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Colonial Museum and Geological Survey Department.

STUDIES IN BIOLOGY

FOR

NEW ZEALAND STUDENTS.

No. 3.

THE ANATOMY OF THE COMMON MUSSELS (MYTILUS LATUS, EDULIS, AND MAGELLANICUS).

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PREFACE.

Some explanation of the style in which this paper is written is desirable, for had I known while preparing it for publication that it was to be published in pamphlet form I would have recast it in a shape more convenient for students' use. It owes its present form to the fact that the original paper was written as a thesis for the New Zealand M.A. examination, and thus naturally included argumentative matter that would be out of place, or, at least, unnecessary, in a paper written specially to serve as a guide to any student wishing to work out the structure of the mussel. The study of types is strongly recommended to biological students by many eminent teachers of natural science, and I trust that this paper, even as it stands, may be of service to some that are seeking to study a type of the Lamellibranchiata. As a subject for study the mussel has the advantages of being readily procurable at most points of our coast, and also of not being so small as to embarrass the tiro in the art of dissection. And here I would protest against the so-called study of the Mollusca in which consideration is had merely of the shell, without reference to the internal structure of the occupant, the only thought of the collector being the speediest method of ejecting the tenant of the shells. It may be, indeed, that hinge-teeth and such-like superficial structures furnish a ready and easy means of classification ; but a true scientific spirit will not be content that the animals themselves, furnishing equally reliable characters, and in many cases having a most remarkable structure, should be rejected as unworthy notice. A thorough study of the anatomy of the molluscs as recommended would doubtless entail much harder work on the part of students of this group, but it would also have a much higher claim to be regarded as scientific work than the cursory methods often adopted.

ALEX. PURDIE.

Wellington, 2nd June, 1887.

LIST OF WORKS REFERRED TO.

It may seem that the following list is a scanty one; but it is to be borne in mind, as accounting for this, that students at this end of the world labour under great disadvantages in the matter of reference libraries of scientific works. There are many works and papers on the Mollusca that have not been within my reach, although aware of their existence and of their scope: hence, if on any point I have shown ignorance of what has already been noted by previous observers, the above is my excuse. In several cases not the original paper but only a brief abstract or review of it was accessible. The numbers given are the numbers appended to the authors' names when referred to in this paper :—

1. Mangili. Nuove Ricerche Zootomiche sopra alcune Specie di Conchiglie bivalvi. Milano, 1804 (abstract),
2. Ducrotay de Blainville. Manuel de Malacologie et de Conchiologie, p. 144. 1824 (abstract).
3. Van Beneden. Annales des Sciences Naturelles, IIe Série, t. 3, p. 198–200, pl. 8. 1835. (Mémoire sur le Dreissena.)
4. Cantraine. 'Histoire Naturelle et Anatomie du Système Nerveux du Genre Mytilina (Ann. des Sci. Nat., IIe Série, t. VII., p. 302, pl. 10. 1837).
5. Duvernoy. Comptes Rendus, XX., 482–484. 1845.
6. Moquin-Tandon. Comptes Rendus, XXXIX., 265–267. 1854.
7. Sabatier. Anatomie de la Moule Commune (Ann. des. Sci. Nat., VIe Série, t. v., pp. 1-132, pl. 1–9. 1877).
8. Hutton, Professor. Manual of the New Zealand Mollusca.
9. Gegenbaur, Carl. Elements of Comparative Anatomy. (Translation.)
10. Milne-Edwards. Sur la Circulation chez les Mollusques (Ann. des Sci. Nat., 1845, IIIe Série, t. 3; and 1847, IIIe Série, t. 8).
11. Peck, R. Holman. The Minute Structure of the Gills of Lamellibranch Mollusca (Quarterly Journal of Microscopical Science, Vol. XVII.).
12. Lacaze-Duthiers. Organes Génitaux des Acéphales Lamellibranches (Ann. des Sci. Nat. 1854, IVe Série, t. II., pl. 5–9).

STUDIES IN BIOLOGY.

THE COMMON MUSSELS.

(Mytilus latus, edulis, and magellanicus.)

This paper describes the structure of the above species of Mytilus, and their general characters are given in "The Manual of the New Zealand Mollusca," page 167. The descriptions refer chiefly to *M. latus*, but frequent comparisons are made where these three species differ. These species are found commonly enough near Dunedin, where my specimens were collected, but they do not seem to range throughout the Islands, except *M. latus*, which is everywhere common. Professor Hutton (8) states that *M. magellanicus* and *M. edulis* are common in the South Island, but not so in the North.

Shell of M. latus. (Plate II.)

Shell wedge-shaped, with a slightly prominent angle about the middle of the dorsal side; ventral side prominent in the anterior half; umbones in some specimens very prominent and diverging; concentric striations more or less evident in the hinder half of the shell. The colour usually serves to distinguish it from *M. edulis*, as the ventral side of *M. latus* is generally an olivaceous-brown, or yellow with green towards the posterior margin; the green colour is seldom altogether obscured, and sometimes in the young is spread over the shell. *M. edulis* is usually dark blackish-blue. The yellow specimens of young Mytilus, referred to by Professor Hutton (8), I find to be not *M. latus*, but *M. edulis*. The shell of *M. magellanicus* is at once distinguishable from the smoother shells of *M. latus* and *edulis* by its longitudinal striations or ribs. In *M. latus* there is usually one very distinct tooth in each valve at the hinge, and the right valve often shows another smaller upper one. The hinge-teeth in *M. edulis* are more numerous; I find several in each valve—not, as given by Professor Hutton, three or four in the left valve and one in the right valve (8).

Sections taken vertically through the two valves (Fig. 7) are somewhat rounded in the anterior third of the shell (Fig. 8, *a*), ovate about the middle of the shell (Fig. 8, *b*), and lanceolate in the hindmost third (Fig. 8, *c*), the wider part of these sections being ventral.

IMPRESSIONS OF THE MUSCLES. (Figs. 4 and 5.)

Taking first the impressions of the adductor muscles, the posterior adductor impression is similar in *M. latus, edulis,* and *magellanicus*. It is a large, distinct oblong or elliptical impression on the upper and hinder part of the shell, distant somewhat less than one-third of the length of the shell from the posterior end. (Figs. 5, 6, and 19, *p ad*.)

Anterior adductor. In *M. edulis* and *magellanicus* this forms a small oval impression on the ventral side at the fore-end of the shell, placed just where the pallial line ends (*a ad,* Fig. 5). In *M. latus* there is no trace of the impression of an anterior adductor (Fig. 4).

Taking next the impressions of the retractors, I shall not now discuss whether they be retractors of the foot or of the byssus, but shall call them indifferently retractors.

Anterior retractor. This is alike in the three species as regards its impression, which is oval and placed close under the hinge at the anterior end of the shell (*a rt,* Figs. 4 and 5).

Posterior retractors. With respect to the impressions of these muscles, a considerable difference obtains between *M. latus* and *edulis* or *M. magellanicus*. In the two last there is an elongate impression just in front of and continuous with the posterior adductor impression. This retractor impression is not quite as continuous in *M. magellanicus* as in *M. edulis,* but the arrangement is the same in both (*p rt,* Fig. 5).

In *M. latus* there is a short muscle impression just in front of and continuous with the posterior adductor impression (*p rt,* Fig. 4); but there is in addition, midway between this and the anterior retractor impression, a very distinct and somewhat large oval impression (*m rt,* Fig. 4).

These two impressions of *M. latus,* if brought together, would form an elongate impression exactly proportionate to that of *M. edulis* and *magellanicus* (Figs. 4 and 5). The first thought is that the continuous muscle impression of these two species has been divided in *M. latus,* part of the muscle being moved forward; and when the muscles themselves are examined this is found to be the case. I have called these middle muscles the "middle retractors:" hence in

M. latus the impression on the upper side about the middle of the shell is that of the middle retractor, while the term posterior retractor impression remains with that part of the retractor impression that is continuous with the posterior adductor impression.

In *M. edulis* or *M. magellanicus* the single impression, called that of the posterior retractor, corresponds to the two impressions of the middle and posterior retractors in *M. latus*.

General Description of the Organs of M. latus. (Fig. 1.)

On opening the valves of the shell and viewing the animal from the ventral side, the body is seen to consist, speaking roughly, of two lateral flaps and a median portion (Fig. 35). The two lateral wings line the shell throughout, and are the mantle-lobes, being spoken of as right or left according to the valve they occupy. The median portion of the body in nearly the whole of the hinder half is a keel-shaped ridge—the mesosoma (*mes*, Figs. 1, 2, and 43). Going forward from the mesosoma, there is first an organ consisting of a central stalk with numerous bristle-like branches, by which the shell is moored to external objects (*bys*, Figs. 1 and 9 : in these figures part of the byssus is cut off). This is the byssus. In front of it, in the median line, is a muscular organ, the foot, whose shape varies much according to the extent of its protrusion or retraction (*ft*, Figs. 1 and 9). At the anterior end of the animal inside the mantle there is, on each side, a pair of depending lobes, the labial palps (*i lp* and *o lp*, Figs. 1, 2, and 28), that nearest the median line on each side being called the inner labial palp, the other the outer labial palp. Between the anterior ends of the labial palps is the mouth (Fig. 1). The mantle-lobes are connected at their posterior end by a nearly horizontal band below the level of the posterior adductor (*j m*, Figs. 1 and 2). This hinder junction is much more extended in *M. edulis* (*j m*, Fig. 3), as it reaches down the greater part of the posterior end of the lobes, starting from above the posterior adductor. The junction of the mantle-lobes in front in *M. latus* extends round the ventral side for some distance. There is a considerable cavity under the mantle at the anterior end, extending in front of the mouth and above the æsophagus between the anterior retractors (*s c*, Fig. 1). This chamber I have called the supra-æsophageal cavity, and mussels kept out of water are often found to have the foot curved round in front of the mouth and reaching into this cavity, which often retains water. Its walls are lined with a rich plexus of blood-vessels.

Extending from between the inner and outer labial palps to the posterior junction of the mantle there are on each side of the foot

and mesosoma a pair of lamellar organs, the gills (Fig. 1; and *i g* and *o g*, Fig. 35). There are two gills on each side, and each gill-plate is doubled upon itself, so that we can distinguish an inner and an outer lamella for each gill. The two gills arise from the same line, and, taking the animal in its proper position, the first lamella of each gill is called the descending lamella as it hangs downward (Figs. 35 and 44). The inner gill is doubled upwards towards the mesosoma, and the outer gill is doubled upwards towards the mantle or shell. The plates or lamellæ thus turned upward are called the "ascending lamellæ." These ascending lamellæ in *M. latus* become attached at their upper side to the mantle or to the body (Fig. 35). By reference to *M. edulis*, in which the ascending lamellæ remain free (Fig. 37), the structure of the gills can easily be explained. From this figure it is seen that the outer lamella of the outer gill and the inner lamella of the inner gill are the ascending lamellæ which are free in *M. edulis* and *magellanicus*; while the inner lamella of the outer gill and the outer lamella of the inner gill are the descending or the original lamellæ of each gill.

Between the two lamellæ of the inner gill in *M. latus*, or by the inner side of the descending lamella of the inner gill in *M. edulis*, near the hinder end of the mesosoma on each side, is a small papilla (*g p*, Fig, 1), the genital papilla. Just behind this papilla is an opening, the renal aperture (*r a*, Fig. 1).

On the upper side of the posterior adductor in *M. latus* or on the posterior side in *M. edulis* is the anus, the latter part of the rectum being prominent upon the muscle.

INTERNAL STRUCTURE.

A great part of the body is occupied by the muscles upon which I have already touched in speaking of the impressions on the shell. The posterior adductor is a large transverse bundle of muscle-fibres extending from valve to valve. The retractors are muscular bands extending from their respective impressions to the base of the foot and byssus (Fig. 1). Above and supported by these muscles lies the main mass of the viscera. The space above the anterior retractors is occupied chiefly by the stomach and the surrounding liver. Above the posterior retractors is the pericardium, containing the two auricles and the ventricle, with part of the rectum which pierces the ventricle (Fig. 1). Below the pericardium are parts of the intestine and pyloric cæcum. The anterior coil of the intestine passes to the left of the stomach. The pyloric cæcum extends into the left mantle-lobe (Fig. 1; and *p c*, Figs. 13 and 14). (A more detailed account will be given under the name of each organ.)

Muscular System.

The muscles of *M. latus* for the more part may be divided into two classes—those that serve to close the shell, the adductors, and those that retract the foot or byssus, the retractors; the latter may again be subdivided, according as they move the foot or the byssus, into retractors of the foot or retractors of the byssus. There is considerable difference between *M. latus* and *edulis* with respect to the arrangement of the retractors, and I shall describe first the muscles of *M. latus*.

Adductors. In *M. latus* there is but one adductor, the posterior one, which is a large muscle, oval in transverse section. Its position has already been described. There is no trace of an anterior adductor. (Figs. 1, 9, 10, and 29.)

Retractors. The retractors of the byssus form the great bulk of the muscles, and of them there are three pair—the anterior, middle, and posterior retractors of the byssus. The anterior retractors of the byssus pass forward between the retractors of the foot, gradually diverging from each other (*a rt*, Figs. 9 and 10), and ending nearly opposite to the cerebral ganglia on either side of the supra-æsophageal cavity (*a rt*, Fig. 1); they are slender rounded muscles. The middle retractors of the byssus are two conical masses of muscle-fibre attached to the shell by the wider end (*m rt*, Figs. 9 and 10), and standing almost immediately above the byssus. The posterior retractors of the byssus are two stout muscles passing back obliquely upwards to the upper anterior corners of the posterior adductor (*p rt*, Figs. 9 and 10). The byssus is then the apex of three muscular Vs, its retractors; the anterior V is nearly horizontal, and is formed by the anterior retractors; the middle V is nearly upright, and formed by the middle retractors; the posterior V leans on the upper corners of the posterior adductor, and is formed by the posterior retractors of the byssus. The foot from its connection at its base with the byssus is of course affected by the contraction of the byssal muscles; but the muscles directly connected with the foot itself—that is, the retractors of the foot—are very small. The retractors of the foot are two muscles not as thick as the anterior retractors at their narrowest part, but widening out somewhat towards their point of attachment to the shell. They curve up round the anterior side of the middle retractors of the byssus, being closely and flatly applied to these muscles, and attach themselves to the shell just above them (*r ft*, Figs. 1, 9, and 10).

In order to compare the muscles of *M. latus* and *edulis* I here give Sabatier's (7) account of the muscular system of the latter. He

says that in *M. edulis* "the anterior adductor is very small; it crosses transversely the anterior hood of the mantle, and is inserted on the inner face of each valve in an impression or groove at the anterior extremity of the lower edge. The middle part of this muscle is included in the thickening of the mantle." He speaks also of the anterior adductor as "so small and rudimentary as to have been overlooked by some observers." In the New Zealand specimens of *M. edulis* it is so evident that only a very careless observer could fail to notice it. (*a ad,* Figs. 5 and 11.)

Retractors of M. edulis. Sabatier states that there are two retractors of the foot, the anterior and the posterior. The anterior retractors of the foot have exactly the position of those muscles that I have above described as the anterior retractors of the byssus in *M. latus,* except that they are connected with the foot and not with the byssus. But Sabatier adds that sometimes these anterior retractors of the foot, instead of stopping at the foot, pass it and join the muscles that work the byssus. What he describes as occasional in *M. edulis* is the constant condition in *M. latus;* that is, its anterior retractors are not retractors of the foot, but of the byssus (*a rt,* Figs. 9 and 10). The posterior retractors of the foot in *M. edulis* are small flattened bands of muscle inserted below the pericardial cavity. These muscles enter the foot and pertain exclusively to it. These posterior retractors of the foot evidently correspond to the muscles described above as the sole retractors of the foot in *M. latus* (*r ft,* Figs. 9 and 10), and the position of these last just in front of the middle retractors of the byssus shows that these middle retractors in *M. latus* arise from the division of the posterior retractors, since in *M. edulis* the posterior retractors of the foot are just in front of the posterior retractors of the byssus. To show this more clearly, compare Fig. 9 with Fig. 11, and suppose that the muscular bundle in the latter *(M. edulis)* were divided and the parts separated: we should in that case have a figure not unlike that in Fig. 9 *(M. latus)*.

"The retractors of the byssus in *M. edulis* are a series of muscular bundles, setting out from the base of the byssus, which spread out into a fan-shaped mass of four or five bundles, and which are inserted on a lengthened, horizontal impression in front of the posterior adductor and below the pericardial region."—SABATIER. (*p rt,* Fig. 31.)

To summarise then the chief differences between the muscular system of *M. latus* and that of *M. edulis* and *magellanicus*—for *M. magellanicus* resembles *M. edulis* except that the posterior retractors

of the byssus are not quite so compact as in *M. edulis* (*p rt*, Figs. 30 and 31)—

(1.) *M. latus* has no anterior adductor, while *M. edulis* has one.

(2.) In *M. latus* the anterior retractors are retractors of the byssus; in *M. edulis* they are generally retractors of the foot.

(3.) In *M. latus* the posterior retractors of the byssus are separated into two bundles, the middle and the posterior retractors; in *M. edulis* the posterior retractors of the byssus are continuous. The posterior retractors of the byssus are also much more compact in *M. latus* than in *M. edulis*.

Pallial Muscles.

The margin of the mantle from the anterior end round to the anterior part of the pericardium or the posterior end of the hinge is furnished on the outer side with muscle-fibres set perpendicularly to the margin. These fibres are called the pallial muscles, and in *M. latus* this edging of muscle-fibre is very broad (Figs. 19 and 29), compared with what exists in *M. edulis* (Fig. 31), and *M. magellanicus* (Fig. 30).

Alimentary Canal. (Figs. 13 to 16.)

The alimentary canal of *M. latus* is of the type that is usual among Lamellibranchs; that is, it consists of a gullet or æsophagus (Fig. 1) opening near the anterior end of the body, and leading into a stomach provided with cæca. The intestine after leaving the stomach makes several turns, finally opening in the anus over the posterior adductor (Fig. 1). The mouth, which is enclosed as in a hood by the union of the mantle-lobes in front of it, is a transverse slit surrounded by two pair of labial palps (Figs. 1 and 28).

The gullet passes back obliquely upwards between the anterior retractors of the byssus, a little above which lies the stomach (*st*, Fig. 1; *stm*, Figs. 13 and 14). The stomach is oval, and in great part hidden by the hepatic cæca, whose ducts enter at all parts of the lower half of the stomach.

From the anterior part of the ventral side towards the left there arises a small diverticulum or cæcum coiled once on itself (Fig. 14A). This is the cardiac cæcum. At the posterior end of the stomach there are two openings, one above the other, from the upper of which the end of the crystalline style often projects into the stomach. The lower one is the opening of the intestine, the upper that of the pyloric cæcum which contains the crystalline style.

The intestine (Fig. 1, and *int*, Figs. 13 and 14) passes back from

the stomach along the floor of the pericardial cavity until it is near the anterior side of the posterior adductor. This part of the intestine I call the direct intestine, as distinguished from the recurrent part of the intestine that succeeds it. Near the posterior adductor the direct intestine turns sharply on itself in a horizontal plane and to the right side (*re int*, Fig. 13), becoming the recurrent intestine. The recurrent intestine runs forward on the right side of the pyloric cæcum and pericardial artery to about the middle of the direct intestine, when it crosses upwards over the direct intestine, pyloric cæcum, and rectum (*rect*, Figs. 13 and 14), to the left side of the stomach, passing between the middle retractors of the byssus. It can now be seen from the left side among the hepatic cæca as it passes down obliquely to the anterior end of the stomach. Near the anterior end of the stomach it turns down and back, being now ventral to the greater part of the liver. It rises gradually as it returns until between the middle retractors of the byssus (Fig. 1), when it is immediately below the recurrent intestine. Then, as the rectum, it passes directly back through the pericardial cavity (Fig. 1), penetrating the ventricle. Leaving the pericardial cavity it goes down the upper surface of the posterior adductor, ending in the anus on the hinder upper side of that muscle (Fig. 1).

The pyloric cæcum, containing the crystalline style, leaves the stomach just above the intestine. It keeps on the upper side of the direct intestine through the whole length of the latter, being very closely applied to it, and almost united with it, yet forming two separable tubes (*p c*, Figs. 13 and 14). When the direct intestine ends and the recurrent intestine begins, the pyloric cæcum continues its course backward alone, now, however, leaving the median line and inclining to the left. It passes above the posterior adductor to the left of the rectum, and enters the left mantle-lobe (*p c*, Fig. 13), gradually tapering as it proceeds. In the left mantle-lobe its course is a little below the thickening of the mantle edge, and the ridge caused by it is easily seen when the anal membranes are cut away (Fig. 1). It forms a curve concentric with that of the mantle edge, entering the thickening of the mantle edge above the posterior junction of the mantle-lobes. It passes the junction, and gradually tapers until it can no longer be followed, having now a course similar to that of the marginal or circumpallial nerve.

There is considerable difference between *M. latus* and *edulis* as to the disposition of the pyloric cæcum and the intestine; and, as I shall have occasion to criticise Sabatier's (7) account of the alimentary canal, it may be well to give his account of the arrangements in *M.*

edulis. He says that in *M. edulis* the stomach is composed of two very distinct parts, one dilated and tapering behind, and one narrow and lengthened out in the form of a tube, which extends back as far as the posterior adductor, where it ends in a small cæcum (Figs. 15 and 16). The anterior part he calls the utricular stomach (*stm*, Fig. 15), and the second the tubular stomach; and he states that the latter contains the crystalline style, which he describes as straight and cylindrical, with its anterior extremity blunt, and its posterior extremity pointed near the intestinal orifice (Fig. 15). He continues thus: "Near the posterior extremity of the stomach [tubular], at the point where the short cæcum commences, one sees on the right side an oval opening very plain and sharply cut out. This is the opening of the intestine, which is left clear by the sharp end of the crystalline style [Fig. 15]. . . . The recurrent intestine is of smaller calibre than the tubular stomach. It is cylindrical. After leaving the tubular stomach in an oblique direction it goes forward and places itself outside and below the rectum." Reference to Figs. 15 and 16 will explain the above description.

In describing what he calls the tubular stomach, Sabatier mentions two parts or semitubes, the upper of which contains the crystalline style, and tapers slightly from before backwards; the lower part of the tubular stomach is a deep channel or gutter, almost enclosed by two longitudinal ridges overhanging it. This channel is of nearly equal calibre throughout.

If, as Sabatier thinks, the crystalline style is enclosed in one of the principal divisions of the stomach, and comes between the main part of the stomach and the origin of the intestine, then *M. edulis* would differ remarkably not alone from *M. latus*, but from other Lamellibranchs, as for instance Dreissena, described by Van Beneden (3) in 1835. Van Beneden states that "the intestine [in Dreissena] sets out from the stomach towards the left side of the animal [Fig. 12], while from the right there arises a cæcal appendage of greater diameter than the intestine, but of firmer texture." In a footnote he adds that "M. de Blainville believes this tube [the cæcum] is a cæcum of the stomach analogous to that which lodges the crystalline style in several bivalves." His figure also shows an arrangement of parts corresponding to that in *M. latus* (compare Figs. 12 and 13).

Gegenbaur (9) states that "in many Lamellibranchs the stomach is remarkable for the possession of a cæcal diverticulum, which is often of considerable size, and can be shut off by a valve: this is placed in the pyloric region. In many forms we meet with a peculiar structure in the cæca, or, when they are absent, in the enteric canal

itself: this, which is known as the crystalline style, is to be regarded as a secretion from the enteric epithelium."

From these quotations the normal position of the crystalline style would seem to be in a distinct cæcum, not in the main line of the enteric canal. Sabatier, however, makes no reference to the position of this structure in other Lamellibranchs, and in no way indicates that he thought the arrangement in *M. edulis* peculiar.

M. latus and *edulis* (with *M. magellanicus*, which resembles it) are so closely allied that we may expect to be able to trace readily the homologous parts throughout all, and, taking any other organs besides the alimentary canal, we can easily find the corresponding parts in all three species. It were strange, then, if this should not hold good also in the case of the alimentary canal. As far as external appearance is concerned, the disposition of the alimentary canal is very similar in *M. latus* and *edulis*, as is seen by comparing Figs. 13 and 14 (*latus*) with Figs. 15 and 16 (*edulis*). In the figure of *M. latus* (Fig. 13) the pyloric cæcum is drawn aside to show the direct intestine, but in the natural position the cæcum is exactly applied above the direct intestine in the middle line.

Suppose, then, the parts thus arranged, and that the cæcum, instead of passing the direct intestine, should end just where the latter ends, we should in that case have a figure exactly like that of *M. edulis* (Fig. 15), as seen from above. *M. latus* exactly resembles *M. edulis* in the position and relations of every other part of the alimentary canal — mouth, gullet, stomach ("utricular stomach" of Sabatier), cardiac cæcum, recurrent intestine, anterior coil of the intestine, and rectum; it is likely, then, that there will be some correspondence in the short tract between the stomach and the posterior adductor.

I would suggest that the part called the tubular stomach by Sabatier is not simply part of the stomach, but represents intestine and cæcum. Its structure as given above favours this supposition. The upper part is already a semitube containing the style, and this semitube tapers from before backwards exactly as does the pyloric cæcum in *M. latus*. The channel ventral to the crystalline style would then represent the direct intestine of *M. latus*, and it is, in fact, partly enclosed by two overhanging longitudinal ridges. A diaphragm below the crystalline style roofing over this channel would form an arrangement exactly comparable to that in *M. latus*, making allowance, of course, for the very abnormal development of the pyloric cæcum in that species. The smallness of the channel taken to represent the direct intestine of *M. latus* may be accounted for by the space round the crystalline style being pressed into service for the

passage of food. As I mentioned above, the pyloric cæcum is closely applied to and almost united with the direct intestine through the whole course of the latter in *M. latus* (Figs. 1 and 14). The separation of the pyloric cæcum and intestine has not proceeded so far in *M. edulis* as in *M. latus* and several other Lamellibranchs, or else, which is less likely, there has been a fusion of two originally distinct tubes. I think this explanation preferable to the suggestion that in two allied species, while the whole disposition of the alimentary canal is otherwise exactly similar, and also the other organs easily comparable, a short part of the alimentary canal should be occupied by totally different structures—in one by part of the stomach, and in the other by part of the intestine and a cæcum of the stomach.

The continuation of the pyloric cæcum into the mantle is perhaps peculiar to *M. latus*, but I have not had any other species than the three above described to dissect for comparison. I have examined the shells of various other species of Mytilus, and find that the muscle impressions agree with those of *M. edulis* and *magellanicus*, the anterior adductor being present and the impression of the posterior retractors continuous, except in the case of *M. smaragdinus*, from China, which exactly resembles the young of *M. latus*, except that the shell is somewhat thinner than that of *M. latus*. This resemblance has been noted by Professor Hutton (8).

Circulatory System.

The heart is placed on the dorsal side just behind the middle, in a large cavity, the pericardial cavity or pericardium (Fig. 1), between the middle retractors of the byssus and the posterior adductor, and lying above the posterior retractors of the byssus. The heart consists of a single central cavity, the ventricle, and of two wings, the auricles (*aur*, Fig. 21). The ventricle is pierced longitudinally by the rectum, which passes through the pericardial cavity (Fig. 1). The auricles open into the sides of the ventricle, and, widening out into a fan-shape, are attached by the wider ends to the sides of the floor of the pericardial cavity. The ventricle is blind at the hinder end, and the aorta sets out from the anterior end (*a ao*, Fig. 21).

Arteries. The main artery or aorta passes forward on the right upper side of the rectum from the anterior end of the ventricle, and soon widens out into a large aortic bulb (*a b*, Figs. 21 and 24), which gives rise to several arteries. From the upper anterior side arise three trunks, the median one being the anterior aorta, and the two lateral ones the anterior pallial arteries (*a p a*, Fig. 21).

The anterior pallial arteries diverge from the aorta and pass down over the middle retractors of their respective sides into the mantle-lobes, soon dividing into two or more large branches, whose ramifications extend over the outer side of the mantle (Fig. 29). The anterior pallial arteries originate as I have above described in both *M. latus* and *edulis,* but in *M. magellanicus* there is a somewhat different arrangement (*a p a,* Fig. 23, and *a p a,* Fig. 30), as the anterior pallial arteries do not spring from the aortic bulb, but from the aorta at points more or less distant from the aortic bulb. It will be well to describe first the course of the anterior aorta in the three species before describing the anterior pallial arteries of *M. magellanicus.*

The aorta, which is easily made out on the dorsal surface for some distance, gradually leaves the median line in *M. latus* and sinks deeper (*a ao,* Figs. 21 and 24), being lost sight of until near the anterior retractors, where it becomes visible in the thin roof of the supra-æsophageal cavity. After it is first lost sight of on the dorsal surface, halfway between the anterior and middle retractors, it passes along the inner wall of the supra-æsophageal cavity to the left side, giving off an artery, where this cavity begins, to the right side (A, Fig. 24). It continues down the left wall of this cavity, being visible on the upper surface only while passing the left anterior retractor, when it begins to incline towards the median line. If the supra-æsophageal cavity be laid open the aorta is readily seen on its wall to the left side. At the anterior end of the mantle the aorta is again in the median line (Fig. 21), and passes down over the anterior end of the mantle to the ventral side, where it divides into two strong arteries, the circumpallial or marginal arteries (*a m a,* Figs. 21 and 24), which follow round the edges of the mantle. These circumpallial arteries send off numerous branches, which ramify in the pallial muscles round the margin of the mantle-lobes (Fig. 29).

The above description of the aorta up to the anterior end of the mantle applies in the main points to *M. edulis* and *magellanicus* as well as to *M. latus,* but from this point there is considerable difference. In *M. edulis* the anterior aorta forks into two at the anterior end of the mantle as in *M. latus,* but the two branches pass only a little way along the ventral side when they break up into capillaries (Figs. 31 and 22). The specimens of *M. magellanicus* that I had for injection were spirit specimens, and therefore not in very good condition. The anterior aorta however in *M. magellanicus* was found to curve round on one side just above the anterior adductor, and then, passing back horizontally a little below the middle of the mantle, to become the anterior pallial artery (Figs. 23 and 30). In the specimens

figured the anterior pallial artery of the other side to the one just described sprung from a point between the aortic bulb and the anterior retractors, but considerably in front of the aortic bulb. There seems to be considerable variation in *M. magellanicus* with respect to the anterior pallial arteries; but in no specimens were they found to start from the aortic bulb.

In *M. latus* and *edulis* then, to summarise the above, the aorta and the two anterior pallial arteries start together from the aortic bulb; in *M. magellanicus* the anterior pallial arteries start from some point of the aorta in front of the aortic bulb, either from the anterior end as a direct continuation of the aorta or from some point midway between the anterior retractors and the aortic bulb (Fig. 23). The anterior aorta in *M. latus* is continued into two circumpallial arteries that pass round the margins of the mantle on the outer sides. The anterior aorta in *M. edulis* ends in capillaries on the ventral edge of the mantle near the anterior end, after dividing into two. The anterior aorta in *M. magellanicus* is continued on one side, at any rate, into the anterior pallial artery, which is not marginal.

In *M. edulis* and *magellanicus* the upper part of the liver and the dorsal surface about the course of the anterior aorta is supplied by somewhat strong, although short, arteries from the aorta, so that the anterior aorta in these two species is well furnished with short arteries, giving off spurs on each side (Figs. 30 and 31).

In *M. latus* the upper part of the liver and the pallial surface above it are supplied chiefly by the anterior pallial arteries, and the deeper parts of the liver by the gastro-intestinal artery yet to be described. The anterior aorta has then very few large lateral branches until it reaches the anterior end of the mantle, where branches are usually sent off to the anterior part of the mantle. These small pallial arteries sometimes spring from the anterior part of the circumpallial arteries (Figs. 21 and 29).

Returning now to the aortic bulbs: From the posterior underside of the aortic bulb there arise two arteries, one passing forwards and the other backwards (*g a* and *p ao*, Fig. 24). The artery that passes back springs from the right side of the aortic bulb, and is the largest of all the arteries. It passes along the median line of the floor of the pericardial cavity, standing out prominently when injected. It is called by Sabatier the pericardial artery, but is in reality the posterior aorta. The artery that passes forward from the underside of the aortic bulb is a smaller artery, but is yet of considerable calibre. It rises from the left side of the bulb below the rectum (*g a*, Fig. 24), and passes forward along the pyloric cæcum on the

left side till near the stomach, when it turns down under the stomach, and its final branches follow and supply the coil of the cardiac cæcum. It is the gastro-intestinal artery.

The two aortas, anterior and posterior, the two anterior pallial arteries (not in *magellanicus*), and one (*M. latus*) or more (*M. edulis*) gastro-intestinal arteries are the main vessels leaving the aortic bulb. I shall now take each of these in turn, and give its course and branches in greater detail than could be done in the above general account.

Anterior aorta in M. latus. The anterior aorta before it enters the supra-æsophageal cavity gives off some small branches to the liver. After entering the supra-æsophageal cavity it gives off numerous branches, so that the walls of this cavity are covered with the fine ramifications of vessels containing arterial blood. As above mentioned, a strong artery is given off from the aorta on the right side (Figs. 21 and 24, A) just at the posterior dorsal end of the cavity. This artery passes round the right wall of the cavity, branching on its route till near the anterior retractor. The other chief artery in this cavity (*tr a*, Figs. 24 and 27) is given off from the aorta a little behind the left anterior retractor, and lies in the floor of the cavity. From the anterior side of this branch, which lies horizontally transverse to the long axis of the body, are given off the arteries that supply both sides of the outer labial palps and the dorsal side of the inner labial palps. The ventral side of the inner labial palps is supplied from another source (Figs. 27 and 28).

From the lower side of the transverse artery just mentioned a strong branch turns downward just at the left side of the floor of this cavity (Fig. 24). It might be quite as correct to say that the aorta gives off a strong artery just behind the anterior retractor, one branch of which forms a transverse artery in the floor of the supra-æsophageal cavity, and the other passes almost directly downward (*a v a*, Fig. 24). In any case, the downward branch passes to the ventral side of the body between the anterior retractors, turning backwards horizontally when it reaches the lower side of the anterior retractors; it runs back in the gutter or groove between these muscles, rising to their upper side when near the foot. It passes then between the retractors of the foot and the middle retractors of the byssus, going under the pedal ganglion, and ends between the bases of the retractor muscles in many fine branches or capillaries. I shall refer to this artery as the anterior ventral artery. Just at the point where the anterior ventral artery turns backward it sends forward a small artery in the median line (*t a*, Figs. 24 and 28),

which bifurcates on the lower lip to supply the ventral side of the inner labial palps. Posterior to the origin of this tentacular artery, and almost opposite the posterior point of attachment of the inner labial palps, the anterior ventral artery gives off on the lower side another branch. This artery runs back in the median line, concealing the anterior ventral artery, and is easily seen on the ventral surface in injected specimens. It passes up the middle of the anterior side of the foot: hence it may be called the pedal artery (*p a*, Figs. 24 and 28). The anterior ventral artery also gives off branches to the liver above it, and to the anterior retractors.

These are the main branches from the anterior aorta in *M. latus*, in which it thus supplies in part the dorsal surface of the body in front of the heart, and also in part the underlying mass of liver; it supplies also the supra-æsophageal cavity, the anterior edges of the mantle, the labial palps, the muscles of the foot and byssus (except the posterior parts of the posterior retractors of the byssus), and the foot itself. All these parts are supplied by the anterior aorta and its branches.

The posterior aorta, or pericardial artery. In *M. latus* it lies in the median line of the floor of the pericardial cavity between the pyloric cæcum and the recurrent intestine. It gives off many branches on each side in the floor of the pericardium, but these are very variable in size and position. One of the strongest branches on each side goes to the edge of the floor of the pericardium, and enters the mantle, there dividing into two strong branches—the posterior pallial arteries (*p p a*, Figs. 21 and 29), which supply the mantle-lobes below the middle retractors and the pericardial region. Leaving, for the present, the smaller branches: the posterior aorta passes back in the median line over the posterior adductor. Anterior to the anus it bifurcates, and a branch passes down each side of the posterior adductor by the sides of the rectum (*p m a*, Fig. 21). These two forks curve down over the posterior adductor, and one enters each mantle-lobe (*p m a*, Figs. 21, 24, and 29), passing backwards obliquely to the margins of the mantle, which they reach a little above the posterior junction of the mantle-lobes. These two forks are visible from the outside of the mantle for some distance before they reach the margin (Fig. 29: in this figure the dotted line shows the part concealed). On arriving at the margin, the main part of each branch of the posterior aorta turns downward and follows the ventral edge of the mantle-lobe of its side, forming the posterior circumpallial or marginal arteries. These posterior marginal arteries run forward and fuse with the anterior marginal arteries formed by the bifurcation of the anterior

aorta, and thus complete a circumpallial circuit between the anterior and posterior aortas in each mantle-lobe (*a m a* and *p m a*, Figs. 21, 24, and 29). A small part of each fork of the posterior aorta turns upward, to supply the margin behind the posterior adductor (Fig. 29).

Returning now to the pericardial cavity: the pyloric cæcum and the posterior retractors of the byssus are supplied by a branch from the left side of the posterior aorta. Just behind the aortic bulb the posterior aorta gives off a small artery to the middle retractors of the byssus, and at the hinder end of the cavity it gives off on its upper side a small artery that passes forward on the underside of the rectum (D, Fig. 24). These are small arteries; but on the ventral side a little in front of the posterior adductor the posterior aorta gives off a large trunk that passes downward in the median line (Fig. 24). Almost immediately this trunk gives off on its posterior side a large artery that enters the posterior adductor (Fig. 24, B) and ramifies throughout it. The rest of the downward trunk passes down in front of the muscle to near the parieto-splanchnic ganglia, still in the median line, when its main branch turns forward at a little more than a right angle, and passes forward nearly horizontally to the anterior end of the mesosoma, giving off in its course lateral branches to the reproductive organs and other surrounding organs. The horizontal part I call the posterior ventral artery, and its course is towards the upper side of the mesosoma in the median line (*p v a*, Fig. 24). From the angle where the posterior ventral artery turns forward, several small arteries are sent backwards to ramify in the membranes about the parieto-splanchnic ganglia. The descending trunk also gives off on its posterior side a small artery (Fig. 23, C), which, keeping close to the adductor, comes to ramify near the ganglia also, this region being well supplied with small arteries.

The posterior aorta and its forks above the adductor give off many small branches. One of these runs forward on the outer side of the pyloric cæcum (Fig. 24), while others supply the mantle-lobes above the posterior adductor, forming small pallial arteries. Behind the posterior adductor each fork of the aorta often sends forward an artery into the mantle below the posterior adductor (Fig. 29). All the pallial arteries previously mentioned are on the outer side of the mantle-lobes, but the branches of the posterior aorta send off behind the posterior adductor each a small artery that runs along the line of attachment of the gills near the posterior adductor on the inner side of the mantle-lobes.

Gastro-intestinal artery. This artery, as already mentioned, springs from the underside of the aortic bulb to the left, and passes

forward along the left side of the pyloric cæcum. From the base of this artery, or from the anterior side of the aortic bulb, a small artery runs forward on the right side of the pyloric cæcum parallel to the large gastro-intestinal artery. To the right of the gastro-intestinal artery, and at the same level, the aortic bulb gives off two small arteries, one to the liver and one to the underside of the recurrent intestine, but none of these is large enough to form a pair with the gastro-intestinal artery, which is nearly median in position, and which may therefore be called an unpaired artery. It is for a distance nearly parallel to the aorta, and is in almost the same vertical plane as the aorta, and sends off all along its course arteries to the hepatic cæca and the portions of the intestine in its neighbourhood. It curves down under the posterior side of the stomach, and becomes coiled nearly horizontally with the cardiac cæcum (*g a*, Fig. 24), which its last branches supply. The gastro-intestinal artery is the main artery that supples the stomach, intestine (anterior coil), and liver. Its branches ramify through the liver, forming a pretty preparation when injected.

It will give a clearer idea of the arrangement of the arteries to review them in connection with the different organs they supply; so I shall describe them in this way.

Arteries to the mantle, or pallial arteries. In *M. latus* the mantle is supplied from two sources, the anterior aorta and the posterior aorta. A line drawn perpendicularly to the long axis of the body from the anterior end of the pericardial cavity would approximately divide the regions of the mantle supplied from the two sources. I shall speak of the part anterior to such a line as the anterior half of the mantle, and of the part behind it as the posterior half. The anterior halves of the mantle are mainly supplied by the ramifications of the anterior pallial arteries (*a p a*, Fig. 29), which pass forward obliquely over the middle retractors. There are also some small pallial arteries sent off into this region from the anterior aorta and the anterior marginal arteries, near the anterior end of the mantle. The posterior halves of the mantle are supplied below the pericardial region by arteries given off from the posterior aorta (*p p a*, Figs. 21 and 29). The portions of the mantle below, behind, and above the posterior adductor are supplied by branches from the forks of the posterior aorta. The margins of the mantle-lobes throughout are supplied by the circumpallial or marginal arteries and their branches, which are short and sub-parallel, like the fibres of the pallial muscles (*a m a* and *p m a*, Fig. 29).

Arteries of the labial palps, or tentacular arteries. First, to define the terms applied to the sides of the palps, in *i l p*, and *o l p*, Figs. 1 and 2, the inner or lower sides of the palps are shown: this side I shall call the ventral side; the upper or outer side will then be called the dorsal side. Most of the arteries to the palps spring from the anterior side of a branch of the anterior aorta, this branch lying transversely in the floor of the supra-æsophageal cavity (*tr a*, Figs. 24 and 27), behind the anterior ends of the anterior retractors. Each palp has two arteries, one on the dorsal side, the other on the ventral side, and these tentacular arteries run along near the anterior edge of the palps. The tentacular arteries, rising then from a branch of the aorta, run forward in the floor of the supra-æsophageal cavity, some of them passing under the commissure between the cerebral ganglia (Fig. 27) to the outer edge of the upper lip. The dorsal tentacular arteries of the outer palps can be seen thence to pass directly round the outer edge of these palps, being superficial in all its length (Fig. 27). The ventral tentacular arteries of the outer palps, and the dorsal tentacular arteries of the inner palps, pass together down by the sides of the mouth, being lost to sight until they appear near the anterior edges of their respective palps (Fig. 28: in this plate the dorsal tentacular artery of the inner palps cannot be seen, but it exactly resembles that figured on the ventral side of the outer palps). The ventral side of the inner palps is supplied by arteries from the anterior ventral artery as previously described (*a v a*, Figs. 24 and 28), but, as this anterior ventral artery is part of the same branch of the aorta as that which gives rise to all the other tentacular arteries (*tr a*, Fig. 24), the whole blood-supply of the palps is derived from the same branch of the aorta.

To explain the exact course of the arteries in the palps, it is necessary to refer to the structure of the palps themselves. The outer palps have a smooth dorsal surface, while the inner palps have a smooth ventral surface. The sides of the palps facing each other—namely, the ventral side of the outer palps and the dorsal side of the inner palps—have a similar and peculiar structure. The anterior margin has an edging of short grooves perpendicular to the margin itself and parallel to each other. Along the posterior ends of these grooves there runs a longitudinal groove, enclosed by a longitudinal ridge or flap, which also overlaps the posterior ends of the transverse grooves. The arteries of these grooved sides—that is, the ventral artery of the outer palp and the dorsal artery of the inner palp—run in this longitudinal groove at a little distance from the edge, and these

arteries do not branch greatly. But on the smooth sides of the palps the tentacular artery runs very near the anterior edge, and sends back on its posterior side numerous sub-parallel short arteries, the posterior ends of which branch and link with their neighbours, forming a kind of plexus on the anterior half of the smooth surfaces of the palps (Figs. 27 and 28). The surfaces having such a plexus are the dorsal side of the outer palps and the ventral side of the inner palps; the sides of the palps that face one another have a single artery. There are then in all eight tentacular arteries, two to each palp: the upper six of these come from the transverse artery in the floor of the supra-æsophageal cavity, while the two lower come from the anterior ventral artery. In one specimen the dorsal tentacular artery of the inner palp was also derived, as the ventral one, from the anterior ventral artery. In this case the outer and inner palps derived their blood-supply from different directions.

Arteries to the muscles and the foot. The artery in *M. latus* that supplies the anterior retractors, the foot, and the apices of the muscular V s formed by the middle and posterior retractors of the byssus springs, as already mentioned, from a branch of the anterior aorta, aud is the anterior ventral artery. The anterior ventral artery passes down just in front of the anterior coil of the intestine, and plunges between the anterior retractors. It turns back between the retractors, giving off arteries to them, also a tentacular artery forward, and a pedal artery to the anterior side of the foot. It passes above the apex of the V formed by the anterior retractors, then under the pedal ganglion, and sends arteries to the base of the byssus and between the bases of the middle and posterior retractors, supplying then the whole muscular floor formed by the anterior retractors, the foot, and the byssus (*p a,* Figs. 24 and 28).

The portions of the middle and posterior retractors near their insertion on the shell are supplied by small arteries from the posterior aorta, or some of its branches. The posterior adductor is supplied by a large artery (Fig. 24, B) from a branch of the posterior aorta, descending in front of it (Fig. 24).

Arteries to the mesosoma, reproductive organs, &c. The mesosoma is supplied by the posterior ventral artery (*p v a,* Fig. 24), whose lateral branches supply the portions of the reproductive organ in its neighbourhood. The parts of the reproductive organ below the pericardium, and not superficial, are supplied by branches of the posterior aorta, and of the descending artery in front of the posterior adductor. The superficial parts of the reproductive organ and those contained in the mantle-lobes are dependent on the pallial arteries for their blood-supply.

Arteries to the stomach, intestine, and liver. The stomach and the parts of the intestine anterior to the pericardium are supplied chiefly by the large gastro-intestinal artery (*g a*, Fig. 24), whose course has already been fully described. Its branches supply the left side of the pyloric cæcum, the anterior coil of the intestine, the underside of the stomach, and the cardiac cæcum. Branches of this artery are sent out into the liver in all directions, and the main central mass of the liver is supplied by it. The superficial portions of the liver are supplied partly by branches from the large arteries near, as from the aorta, anterior pallial arteries, or from the anterior ventral artery. The right side of the pyloric cæcum in front of the aortic bulb and the portions of the liver and intestine near the aortic bulb are supplied by branches from the base of the gastro-intestinal artery, or from the aortic bulb. The portions of the alimentary canal lying in the floor of the pericardium are supplied by the branches of the posterior aorta. The underside of the rectum at the anterior and also at the posterior end of the pericardium receives a small artery; from the upper side of the posterior aorta at the latter point (Fig. 24, D), and from the base of the gastro-intestinal artery or the outside of the aortic bulb at the former point. The whole course of the alimentary canal is covered by a very fine system of capillaries.

Comparison of the Arterial Systems of M. edulis and M. latus.

I have not been able to give time to work out the whole arterial system of *M. magellanicus*, and therefore cannot speak of it except with regard to its chief arteries. Of these, its anterior aorta and pallial arteries have been above described, and its posterior aorta resembles that of *M. edulis*.

It may be stated as the general rule that in *M. latus* a single unpaired artery is made to take the place of paired arteries in *M. edulis*; that is, the tendency in *M. latus* is to have a single median vessel where *M. edulis* has two parallel vessels a little to the sides of the median plane. The arterial system of *M. latus* is single and median; that of *M. edulis* double and equilateral. The point of this comparison will best be understood by referring to the general sketch of the arterial system of *M. latus* (Fig. 21). Here, taking the anterior aorta and the posterior aorta as one, and overlooking the divergence of the anterior aorta, it is seen that the arterial system has a main, single median trunk dividing at the anterior and posterior ends only when the separation of the mantle-lobes compels this division. The gastro-intestinal artery, which is not shown in Fig. 21,

is also unpaired (*g a*, Fig. 24), and nearly median under the aorta. The arteries to the mesosoma and to the muscles, that is, the two ventral arteries, with the arteries to the foot and even to the ventral side of the inner palps, are all unpaired and median.

In *M. edulis* the anterior and posterior aorta are also unpaired and median, but the latter is a very small, insignificant artery, supplying only the floor of the pericardium, and not the underlying organs (*p ao*, Figs. 25 and 26: in Fig. 25 the posterior aorta or pericardial artery is left white to show upon the dark gastro-intestinal artery). All the important arteries to the stomach, liver, intestine, and to the sides of the body are paired arteries. From the underside of the aortic bulb in *M. edulis* there springs a short trunk (the cœliac trunk of Sabatier), which gives rise to three branches or arteries, the median being the small pericardial artery or posterior aorta above mentioned; the lateral branches are large, and are the gastro-intestinal trunks (Fig. 25). These trunks divide into the anterior and posterior gastro-intestinal arteries (*g a*, Figs. 25 and 26). The anterior gastro-intestinal arteries pass forward on each side of the pyloric cæcum, and supply the stomach, intestines, &c. They also give rise near their base to two long arteries which run back one on each side of the body, and are called by Sabatier the recurrent arteries (*r a*, Figs. 25 and 26). The recurrent arteries supply the parts of the genital organ on the sides of the body, and their lower branches supply the sides of the mesosoma. The posterior gastro-intestinal arteries run back one on each side of the pyloric cæcum, and supply between them the parts of the alimentary canal below the pericardium. Thus, in *M. edulis* the anterior and posterior gastro-intestinal arteries and the recurrent arteries forming a great part of the arterial system are paired and lateral; in *M. latus* these are replaced by the gastro-intestinal artery, the posterior aorta or pericardial artery (which is very small in *M. edulis*), the anterior and the posterior ventral arteries, which are all unpaired and median.

Another remarkable point of difference between these arterial systems is the want of the marginal arteries in *M. edulis*, which are so strongly developed in *M. latus*. In *M. edulis* the anterior aorta bifurcates at the anterior end, but it does not pass far round the mantle before it breaks up into capillaries (Fig. 31), and there is no account given by Sabatier (7) of any continuation of the pericardial artery or of any of the posterior gastro-intestinal arteries into the posterior part of the mantle. The muscular borders of the mantle in *M. edulis* are supplied by fine capillaries from the ends of the branches of the pallial arteries, which approach much nearer the margin of the

mantle in consequence in *M. edulis* (Fig. 31) than in *M. latus* (Fig. 29). It is noteworthy, in connection with the presence of the marginal artery, that the border of pallial muscles is much wider in *M. latus* than in *M. edulis* (Figs. 29 and 31). Instead of a marginal artery, however, there is in *M. edulis* a marginal sinus or vein following the edge of the mantle (*m s*, Fig. 32) : this marginal sinus is not present in *M. latus*.

As to the disposition of the pallial arteries, there is great difference between the three species *M. latus, edulis,* and *magellanicus*. In *M. edulis* and *magellanicus* the whole of the mantle is supplied by pallial arteries springing from the anterior side of the aortic bulb in the former, and from the anterior aorta in the latter (Figs. 22 and 23); the arteries from the anterior side of the aortic bulb in *M. latus* supply only the anterior half of the mantle (Fig. 21). This difference is probably due to the disposition of the muscles. In *M. edulis* and *magellanicus* the retractors are so arranged as to form an almost continuous wall below the pericardial region, thus forcing the pallial arteries to pass round the anterior end of this barrier. In *M. latus* the lower side of the pericardial region is quite free from any such obstruction, on account of the separation of the middle and posterior retractors. This, together with the great development of the posterior aorta, renders it natural that in *M. latus* the posterior halves of the mantle-lobes should be supplied from behind the aortic bulb or from the posterior aorta, as is the case. With regard to the continuation of the anterior aorta and also of the posterior aorta into a circumpallial circuit, this would seem to be unique, so far as I have been able to see. No account of any such arrangement has been described in any Lamellibranch. On the contrary, Gegenbaur (9) gives a very different arrangement as the normal condition in Lamellibranchs. He says that "the anterior arterial trunk [anterior aorta] passes *as far as the region of the mouth,* where it gives off branches and opens into wide hæmal spaces. The posterior arterial trunk [posterior aorta or pericardial artery], the length of which is dependent on the development of the hinder portions of the mantle, which represent the siphons, *also passes into hæmal spaces or lacunæ.*" [Italics mine.]

Venous System.

This, in *M. latus,* is very difficult to work out, as it consists in great part of lacunæ or hæmal spaces, and the softness of the tissues demands the greatest care in the operation of injection, else the injection may take almost any course. Milne-Edwards (10), in giving

accounts of his researches in several molluscs, points out and emphasizes the frequent substitution among molluscs of unwalled blood-spaces for vessels with definite walls in various parts of the blood circuit. It happens thus in *M. latus* that while the arterial system is remarkably well developed the venous system is the reverse, and is, in fact, not nearly so well defined as in *M. edulis,* whose arterial system is not quite equal to that of *M. latus.*

It will be well to take first Sabatier's (7) account of the venous system of *M. edulis,* in which the veins are well defined, for, by reference to this, the condition of *M. latus* can be more readily explained. In *M. edulis* the blood from the pallial arteries and other arterial vessels is collected mainly in the large marginal sinus (*m s,* Fig. 32), from which it finds its way either directly at the posterior end of the mantle or else by means of small veins (ascending veins) on the inner surface of the mantle to a horizontal venous sinus extending along the mantle below the level of the posterior adductor, and called the horizontal vein (*h v,* Fig. 32). From the upper side of this horizontal vein numerous very fine vessels arise on the inner surface of the mantle; these very fine veins divide and occupy the external side of the so-called *organes godronnés.* These "organes godronnés" are transverse bands very loose or lacunar in structure, which connect the mantle and the base of the descending lamellæ of the gills. They are almost rudimentary in *M. latus* (Fig. 2), although well developed in *M. edulis* (*o gd,* Fig. 3) and *magellanicus.* These organs are held by Sabatier to function as gills in the respiration of the blood. In *M. edulis,* according to Sabatier, the blood conveyed upwards as we have seen by very small vessels from the horizontal vein enters the lacunar tissue of the "organes godronnés." Leaving them, the blood may take slightly different courses. It may pass directly into the longitudinal vein (Fig. 32), and from thence be conveyed directly to the auricle by the oblique vein (*o v,* Fig. 34): this happens especially in the anterior half of the longitudinal vein. Or, leaving the "organes godronnés," it may traverse a considerable part of the organ of Bojanus (which surrounds the longitudinal vein in part, and is interposed between it and the "organes godronnés"), and thence enter the longitudinal vein to be conveyed to the auricle by the oblique vein. This happens especially in the posterior part of the longitudinal vein, where the masses of the organ of Bojanus so obtrude themselves on the longitudinal vein as often to break up and obscure the cavity of the vein. In the preceding cases the blood has returned to the heart without passing through the gills. Behind the posterior adductor, where the "organes godronnés" do not exist, a

connection is made between the hinder part of the horizontal vein and the posterior part of the organ of Bojanus and longitudinal vein by an obliquely-placed vein, the anastomosing vein (*a v*, Fig. 32). This anastomosing vein receives on its course a vein from the sinus among the fibres of the posterior adductor; this sinus also sends a vein to the horizontal vein to the front of the posterior adductor. This double communication, Sabatier suggests, prevents the bursting of the vessels through undue extension, since the blood, collecting rapidly and failing to find a course in one way, by a reflux action may avail itself of the other outlet. The blood from the mesosoma in *M. edulis* returns by more or less lacunar passages to the region of the organ of Bojanus and the longitudinal vein. There is a very large venous sinus enclosed between the anterior retractors, which collects the blood from the anterior part of the body; and there are other hæmal spaces among the bases of the muscles of the foot and byssus. These intermuscular sinuses collect the blood returning from the surrounding organs—the liver, the muscles, foot, &c.—also in part from the mesosoma. The blood from these various sources penetrates from the hæmal spaces into the lacunar tissue of the organ of Bojanus, and thence in part to the gills and in part directly back to the heart by the longitudinal vein. The blood that enters the gills traverses the gill-filaments, and is collected by the efferent vessels of the gills which lie on the upper edge of the free or ascending lamellæ. The efferent vessels carry the blood forwards and throw it into the anterior ends of the longitudinal veins between the bases of the labial palps. To summarise the above, the venous blood passes from the marginal sinus or from the ascending veins into the horizontal vein, thence by small vessels into the "organes godronnés," and thence, either directly or through the tissue of the organ of Bojanus, into the longitudinal vein, and from that to the heart. The other course is to interpose the gills between the organ of Bojanus and the longitudinal vein, in which case the blood is conveyed to the anterior end of the longitudinal vein by the efferent branchial vessels. The blood may also be collected by various sinuses and thence introduced to the organ of Bojanus, to follow afterwards either of the above courses.

In *M. latus* the longitudinal vein has well-defined walls, and it extends from near the anterior retractor impression to the posterior adductor, widening as it goes backward (*l v*, Figs. 29 and 33). It lies just along the line of attachment of the descending lamellæ of the gills, and, when injected with colouring matter, is visible through the bases of the gills when they are separated.

The ascending veins are represented by fine channels in the substance of the mantle, which are easily made out on the inner side of the mantle (Fig. 2); but these channels have no definite walls, and injection introduced into them spreads at once through the neighbouring substance. There is no marginal sinus. The horizontal vein, as far as I can make out, is represented by a long lacunar space, from which the blood probably enters the organ of Bojanus.

I have never succeeded in making any injection, fluid or otherwise, enter the gill-filaments; but there is an efferent vessel along the dorsal edge of the ascending lamella of each gill. These efferent vessels are frequently injected and pass forward to between the bases of the labial palps, as described in *M. edulis*. Their course is marked in Fig. 2 by the dotted lines marking the lines of attachment of the ascending gill-lamellæ.

Large intermuscular sinuses exist as in *M. edulis*, and there is a fine plexus of veins over the surface of the mesosoma, but these seem to have porous or incomplete walls, as the injection immediately diffuses into the surrounding tissue. The whole tissue in the neighbourhood of the organ of Bojanus is lacunar, and, in injecting from the foot, is readily filled with injection.

The horizontal vein is similar in position in *M. latus* and *edulis*, but it communicates with the auricle in somewhat different points (Figs. 33 and 34). The oblique vein, as Sabatier terms it, in *M. edulis*, passes up over the anterior side of the posterior retractors to enter the anterior end of the auricle. If the oblique vein in *M. latus* had a corresponding position it would pass up over the anterior side of the middle retractors to the auricle; but this is not its position. It lies between the middle and the posterior retractors, and enters the auricle about the middle of its length (*o v*, Fig. 33). This seems another result of the differences between the retractors of *M. latus* and *edulis*. *M. magellanicus* resembles *M. edulis* in this point. The oblique vein of *M. edulis* and *magellanicus* lies in a large "couloir" or passage opening into the pericardium, but there is no such passage or opening into the pericardium in *M. latus* (*coul*, Figs. 31 and 34).

To summarise, then, the condition of the venous system in *M. latus*: The blood conveyed from the heart by the pallial arteries and aorta on the outer side of the mantle returns for the most part in the case of the mantle by short channels, branching among the reproductive products and growing wider as they ascend on the inner side of the mantle. These represent the ascending veins of *M. edulis*, but are not furnished with definite walls. The blood from these ascending channels seems to collect in a large sinus occupying the position of

the horizontal vein in *M. edulis*. This sinus lies in the mantle just below the level of the organ of Bojanus; and this organ and the surrounding tissues are so lacunar that they act as a long blood-sinus extending along the base of the gills. The blood from the foot, mesosoma, muscles, and liver is collected in extensive intermuscular ventral sinuses, and from them conveyed to the spongy tissues about the organ of Bojanus: thus the whole blood of the body returns to this neighbourhood. Some of it may pass directly into the longitudinal vein, as I have found in front of the middle retractors small channels leading up to the longitudinal vein like those above the horizontal vein in *M. edulis* (Fig. 32), but the great part of the blood must pass into the tissue of the organ of Bojanus, which surrounds the longitudinal vein. The injection always enters the organs corresponding to the "organes godronnés" of *M. edulis* (*o gd*, Figs. 2 and 3); but these are so small in *M. latus* that they cannot greatly affect the aëration of the blood. From the tissues of the organ of Bojanus the blood will in part be transfused into the longitudinal vein, and thence to the auricle. Part of the blood probably passes through the gills in the natural course of the circulation, since there are efferent branchial vessels, although the injection, possibly finding the course into the longitudinal vein easier, refuses to enter the gills. But the fact, noted by Sabatier, that a great part of the blood returns to the heart without passing through the gills is very evident. As accounting for this, it may be that the blood exposed to the water on the inner side of the mantle, and possibly also to water entering the organ of Bojanus (although the function and action of this organ are not altogether settled), is sufficiently aërated without the further aëration obtained in passing through the gills.

The investigation of the relations of the organ of Bojanus and of the longitudinal vein is attended with great difficulties, for, while in front of the entrance of the oblique vein the channel of the longitudinal vein is well defined, in the part behind the oblique vein the organ of Bojanus, which is very irregular, projects into the channel of the vein, and, as the tissues separating them are very delicate, injection often proves a very unsatisfactory method of defining the limits of the vein.

Organes Godronnés, or Plaited Organs.

For convenience I shall use the term "plaited organs," as a substitute for Sabatier's term, "organnes godronnés." These organs and their position have already been referred to. They are transverse lacunar bands of tissue communicating between the mantle and the

bases of the gills and neighbouring organ of Bojanus (*o gd*, Figs. 2, 3, 35, and 37). While they are large and noticeable organs in *M. edulis* and *magellanicus*, they are very small and inconspicuous in *M. latus*. They are mentioned by Sabatier as existing only on the outer side of the gill (*o gd*, Fig. 3) in *M. edulis;* but I think the transverse bands occupied by the organ of Bojanus on the inner side of the gill anterior to the mesosoma in *M. edulis* are exactly comparable to the bands on the outer side of the gill opposite the mesosoma, which are alone termed "organes godronnés" by Sabatier. In *M. latus* the descending lamellæ of the two gills are attached along one line between the mantle and the mesosoma (Figs. 2 and 35), as is the case in *M. edulis,* but the further arrangement of the gills differs slightly. In *M. latus* the descending lamellæ do not hang directly downward from the line of attachment, but diverge from each other; and a little from their base is another point of attachment (Fig. 35) in the case of the inner gill to the body and of the outer to the mantle. The means of attachment are small triangular vertical plates exactly answering to the plaited organs of *M. edulis* and *magellanicus,* one passing to each filament. These small plates exist along the whole course of the gills from their anterior end to where the gills become free at the posterior adductor. The continuation of these transverse connections the whole length of the gills in the case of both lamellæ is my reason for considering the plaited organs of Sabatier and the transverse bars on the anterior part of the organ of Bojanus in *M. edulis* and *magellanicus* as exactly similar structures, as they are quite homologous with these small vertical plates of *M. latus,* which are uniform throughout and differ only in size from the above organs. Sabatier ascribes to the plaited organs an important part in the aëration of the blood, and in this I think he is right; but, since we have seen that the organ of Bojanus takes an important part in this operation, then the transverse bands in *M. edulis* on the inner side of the descending lamellæ may well be considered as plaited organs that happen to be occupied by the organ of Bojanus. Sabatier, while giving very great prominence to the plaited organs on the outer side of the gill, has made but slight mention of these bars on the ventral side of the gill, and has not noted their resemblance to the structure to which he has restricted the term plaited organs, or "organes godronnés." In *M. edulis* these organs are not developed on the outer side anterior to the mesosoma, nor on the inner side behind the anterior end of the mesosoma (*o gd*, Fig. 3).

The function of the plaited organs as respiratory organs helps to explain the difference in their development in *M. latus* and in *M. edulis*. In *M. edulis* the outer lamellæ of the gills are free, and in *M. latus* they are attached throughout. The result is that, in *M. edulis* and also *magellanicus*, when the mussel is open under water the angles between the mesosoma and gill, and between the gill and the mantle, will be laved by water constantly renewed. In this case it would be of advantage to the animal to have delicate tissues that could function as respiratory organs: hence probably the great development of the plaited organs in *M. edulis* and *magellanicus*. In *M. latus* the outer lamellæ are fastened down, and, although there is doubtless a current of water through the gills, yet the facility given for aëration of the blood will not be as great as in the two preceding species, and the plaited organs are consequently small. It is not easy to determine the primitive condition of these organs. If it is true that they are always greatly developed when the outer gill-lamellæ are free, then, since this is the primitive condition of the gill, the state of the plaited organs as we find them in *M. latus* would be secondary, or a case of degeneration through loss of function. The bending of the gill-lamellæ at their base (Fig. 35) through the attachment of these plaited organs is certainly a peculiar point, since if they were more developed the descending lamellæ would take the normal or vertical position as in *M. edulis*.

Note.—In explanation of Fig. 2, I may say that it represents the gill-lamellæ as cut off exactly along the line of attachment by the rudimentary plaited organs.

Aquiferous System.

I have not been able to investigate this system. Sabatier states that there is communication between the blood-system and the water, the opening to the exterior being by a pore in the foot.

Gills. (Figs. 35 to 40.)

In the general structure of its gills *M. latus* resembles the other species of Mytilus; that is, its gills are two on each side; each gill consists of an ascending and a descending lamella, connected by bars called interlamellar junctions. The gills are made up of filaments placed one behind the other, and bent upon themselves to form the two lamellæ of each gill (Figs. 35 and 37). The filaments are linked together by ciliated interfilamentar junctions. In *M. edulis*, as figured by Peck (11), there are several interlamellar junctions in one filament, which are placed one near the ventral side of the lamella, and the

others, several together, higher up near the middle of the lamellæ (*i l j*, Fig. 38). In *M. latus*, in all I have examined, there were two or at most three interlamellar junctions to one filament, and these were placed one, as in *M. edulis*, near the ventral side of the lamella, one near the middle of the lamella (*i l j*, Fig. 36), and the third, which existed only in very long filaments, still higher up near the base of the gills. In no case were there two interlamellar junctions close above one another as we have them represented near the middle of the filaments in *M. edulis*. The outer and inner lamellæ are thus more strongly connected by interlamellar junctions in *M. edulis* than in *M. latus*; and this may be necessary, as the ascending lamellæ in *M. edulis* are free at their upper edge, and would thus be more liable to be torn apart from the descending lamellæ than in *M. latus*, whose ascending lamellæ are joined at their upper edges to the body or mantle (Figs. 35 and 37).

The interlamellar junctions about the middle of the filaments are found to be arranged in a very peculiar fashion, when we regard the whole length of the lamella in *M. latus*. On looking through the two lamellæ of a gill, about the middle there are seen a series of short oblique portions more opaque than the rest (*i l j*, Fig. 39), and occupying the middle line or long axis of the gill. On separating the filaments, it is found that these opaque portions are formed by the middle interlamellar junctions. Each of these opaque bars extends over about fifty filaments, and they are obliquely placed because in each set of fifty filaments the middle interlamellar junction of any one filament is a little higher than that of the gill preceding. In *i l j*, Fig. 40, I have attempted to show this arrangement diagrammatically. This figure represents a portion of a gill in which a number of succeeding filaments have been separated and turned round to show the interlamellar junctions. If, in this figure, instead of only five filaments there were fifty or more, it would represent roughly a part of a gill crossed by one of the oblique bars of interlamellar junctions.

The interfilamentar junctions in *M. latus* are not exactly in the central line of each filament, as represented in Peck's figure of *M. edulis* (*i f j*, Fig. 38), but are near the edges (*i f j*, Fig. 36).

The ascending lamellæ in *M. magellanicus* are free, as in *M. edulis*.

"Cavité des flancs" (Sabatier).

This opening is of no great importance, except as marking a constant difference between *M. latus* and *edulis* or *magellanicus*, as it

exists in all specimens of the two last species that I have examined. It is a space or cavity in the region of the posterior retractors, with an opening near the hinder end of the mesosoma, and varies according to the condition of the animal. Sabatier suggests that the existence of the cavity is due to the great development of the posterior retractor muscles: but there is no such cavity in *M. latus,* whose posterior retractors are equally well developed, although differently arranged. It may be owing to the posterior retractors of *M. edulis* and *magellanicus* forming a single large bundle of muscle that a clear space is necessary for their free action.

There is one of these cavities in each side, and their openings are shown in Fig. 3 posterior to the inner side of the genital papillæ. Their position is similar in *M. magellanicus,* but there is no such opening or cavity in *M. latus.*

Organ of Bojanus.

So far as the disposition of the main part of this organ is concerned, there is little difference in *latus, edulis,* and *magellanicus.* It is formed of two brownish masses stretching along the ventral side of the body, one on each side of the mesosoma and foot, and opening posteriorly by an aperture immediately behind the genital papilla of each side (*r a,* Fig. 1). The ventral side of the organ in the anterior half is in *M. edulis* and *magellanicus* continued into transverse bars or ridges between the base of the gill and the foot, while in *M. latus* there are no such ridges. The relations and function of these ridges were discussed while considering the "organes godronnés." The organ of Bojanus functions as a renal or excretory organ, and it is usual in Mollusca that these organs should have two openings, one to the exterior usually closely connected with the genital aperture, and one internal, into the cœlome or the pericardium representing it. There is a great difference between *M. edulis* and *latus* with regard to this internal opening.

In *M. edulis* and *magellanicus* there are two openings in the floor of the pericardium, one on each side in the anterior part (Fig. 34). From each of these a large oblique channel (called by Sabatier the *couloir péricardique*) passes round the anterior side of the posterior retractor of its side to the organ of Bojanus (*coul,* Fig. 34). In the posterior part of this "couloir" lies the oblique vein. Sabatier finds by injecting the pericardium or the organ of Bojanus that this "couloir" forms a direct and ready communication between the pericardium and the organ of Bojanus; hence it represents the internal opening of the excretory organ into the cœlome. In *M. latus* the

oblique vein does not lie in any large passage or "couloir" (*o v*, Fig. 33); and the floor of the pericardium, so far as I can find, is intact except where it is pierced by the oblique vein. The substance of the organ of Bojanus surrounds the oblique vein right up to the floor of the pericardium, but there is no communication between the pericardium and it round the neck of the oblique vein. However, the oblique vein in *M. latus* has a different position in relation to the posterior retractors from what is the case in *M. edulis*, and the position in *M. latus* corresponding to that of the "couloir" in *M. edulis* would be just in front of the middle retractors of *M. latus* (compare Figs. 33 and 34). But there is no communication between the pericardium and organ of Bojanus in front of the middle retractors, although the cavity of the pericardium extends into two blind prolongations above these muscles (Fig. 33). In *M. latus* I have been unable to find, either by injection or dissection, any communication between the organ of Bojanus and the pericardium; and, since such a passage is so easily seen in *M. edulis*, I am inclined to think that the internal opening of the renal organ is lost in *M. latus*. In that case the organ of Bojanus will have departed further from the primitive condition or become more modified in *M. latus* than in *M. edulis* or *magellanicus*.

Nervous System.

[I omit here part of the original paper containing a short historical account of our knowledge of the nervous system of Lamellibranchs.] The nervous system of *M. latus* consists of three pair of ganglia, the two hindmost pair being each connected with the anterior pair by stout nerve-cords. The anterior ganglia have been termed the cerebral, anterior, or buccal; the median ganglia the pedal or median; and the posterior ganglia the visceral, posterior, or parieto-splanchnic. In each case I shall use the first as here given—namely, cerebral, pedal, and visceral (*c g*, *p g*, and *v g*, Figs. 1 and 17). In the plate of the nervous system (Fig. 17) it is seen that the ganglia in each pair are connected with each other as well as with the ganglia of another pair. It has been recommended that the term "commissure" be employed to denote the connecting nerve-cord between two ganglia of one pair, while the term "connective" should be applied to the nerve-cords connecting ganglia of different pairs. Using these terms, then, the main part of the nervous system of *M. latus* consists of three pair of ganglia—the cerebral, the pedal, and the visceral; of three commissures—the cerebral, the pedal, and the visceral; and of two pair of connectives—the cerebro-pedal and the cerebro-visceral.

The cerebro-pedal and the cerebro-visceral connectives are fused, or have a common stem, for part of their course in *M. latus*.

The cerebral ganglia. These are placed on the dorsal surface of the gullet, rather more than a third of its length from its anterior end, and well apart from each other (*c g*, Figs. 1 and 17). They are connected by a distinct supra-æsophageal band, the cerebral commissure, and give off each two principal branches: (1.) An anterior nerve, which passes along the outer dorsal surface of the gullet, visible from the surface, until it reaches the anterior end of the outer labial palp, when it curves downward (Fig. 1, and *a m n*, Fig. 19). It keeps a somewhat direct course downward till it reaches the centre of the thickening of the mantle-edge, then it turns backward and passes along in this thickening till it meets and fuses with a similar nerve from the visceral ganglia (Figs. 1 and 19). This marginal nerve-circuit is the circumpallial or marginal nerve, and the part of it near the cerebral ganglia is the anterior marginal nerve, that near the visceral ganglia the posterior marginal nerve. It forms an additional connection between the cerebral and visceral ganglia, already connected by the cerebro-visceral connective. The course of this nerve resembles that of the circumpallial or marginal artery. (2.) The other main branch from the cerebral ganglia is the stout nerve-cord from each ganglion that passes back along the side of the body to connect with the pedal and visceral ganglia (Fig. 17). Each of these connectives sets out from the outer posterior corner of its ganglion, and passes back nearly along the line of attachment of the inner labial palp of its side and ventral to the main mass of the liver. A little behind, where the palp becomes free, each connective divides into two, then called the cerebro-pedal and the cerebro-visceral connectives, according to their destination. The cerebro-pedal connectives turn in towards the pedal ganglia, which they join (*c p c*, Figs. 1 and 17). The cerebro-visceral connectives run inside the line of attachment of the ascending lamellæ of the inner gill till about opposite the foot (*c v c*, Fig. 2), when they cross to the outer side of this line, and then run along the upper side of the mesosoma, between the lines of attachment of the lamellæ of the inner gills. As the mesosoma tapers the cerebro-visceral connectives approach each other, finally joining the anterior ends of the visceral ganglia just behind, and dorsal to the genital papillæ on the ventral side of the posterior adductor (Figs. 1 and 2). There are other smaller nerves from the cerebral ganglia, but these I shall describe further on.

The pedal ganglia. These lie on the dorsal side of the angle formed by the two anterior retractors of the byssus just in front of

the retractors of the foot (Fig. 1). The pedal commissure can hardly be said to exist, as the two ganglia themselves are so closely applied that they might be spoken of as a single ganglion; but a slight inspection convinces one that there are two ganglia. As above mentioned, there are two stout nerves on the anterior side—the cerebro-pedal connectives. Besides these connectives the pedal ganglia give off from each side four nerves, the largest of which enters the foot (*p n*, Fig. 17).

Visceral ganglia. These lie under the forepart of the posterior adductor, closely applied to it just above the last point of attachment of the mesosoma, near the genital papillæ (*v g*, Fig. 1). These ganglia are some distance apart, and connected by a strong band, the visceral commissure. In addition to the cerebro-visceral connectives there are two very strong nerves given off from each of these ganglia: (1.) From the posterior corner of each ganglion a strong nerve passes back along the dorsal edge of the gills. These are the gill-nerves. (2.) Rising dorsal to the gill-nerves a flat, broad nerve passes from each ganglion back along the ventral side of the posterior adductor (Fig. 17), and about the posterior end of the muscle divides into two (Fig. 19), one branch turning in a ventral direction, and the other upwards. The dorsal branch curves up round the adductor, and at the edge of the mantle divides into two branches, which supply the margin of the mantle above and behind the posterior adductor (*m n* 3, Fig. 19). This I call the third posterior marginal nerve. The ventral branch of the main nerve below the adductor also enters the mantle, soon dividing into two nerves, the smaller of which (the second posterior marginal nerve, *m n* 2, Figs. 17 and 19) takes a nearly horizontal course towards the junction of the mantle-lobes. The main branch continues the curve downward, being visible from the outer surface of the mantle till it reaches the ventral edge of the mantle (*m n* 1, Fig. 19), which it follows forward within the thickened margin till it joins the interior marginal nerve, completing the circumpallial circuit. This last branch is the first posterior marginal. All the nerves above mentioned are comparatively easy to trace, but the rest of the nerves are so delicate that it is with the utmost difficulty they are followed through the substance of the surrounding organs. Repeated and careful dissections are necessary, and the slenderness of the nervelets causes frequent failure, even where great care is taken. In many cases I have failed to fix the destination of these small nerves, and because of this uncertainty in the case of some I have thought it better to give first an account of the stronger nerves whose course was plain, and then apart from these a list of the nervelets.

Smaller nerves. Each cerebral ganglion gives off between the anterior marginal nerve and the cerebro-visceral connective two small nerves (Fig. 17), the anterior of which goes to the outer labial palp of its side, and the posterior one goes almost directly outward towards the inner labial palp, giving off a small branch on the anterior side. There is also a pair of small nerves given off between the anterior marginal nerves. The anterior marginal nerves give off a small branch into the mantle.

Each pedal ganglion gives off four nerves behind the cerebro-pedal connectives. The most anterior is a small nerve that becomes lost in the connective tissue round the retractors of the foot (Figs. 17 and 20). From the outer and hinder corner of each ganglion two nerves are given off; the anterior is very large, and enters the foot, being the pedal nerve; the posterior of the two is smaller, and supplies the base of the byssus and the anterior part of the mesosoma, being the byssal nerve (*b n,* Figs. 17 and 20). From the posterior side of the ganglia a pair of small nerves arises, the nerves being close together. These supply the middle and posterior retractors (Figs. 17 and 20).

The visceral ganglia give off on the anterior side between the cerebro-visceral connectives a pair of fine nerves that run forward. These I have traced into the connective tissue round the posterior retractors of the byssus. Rising from the same part is a pair of delicate nerves that supply the dorsal edges of the mantle and have a very curious course. These nerves (the dorsal marginal nerves) rise from the anterior dorsal surface of the visceral ganglia, and, taking an oblique course upwards in front of the posterior adductor, pass between the posterior retractors (*d m n,* fig. 19). They continue this slanting course upwards till they arrive at the mantle-edges above the pericardium, where they form marginal nerves. I cannot find a similar pair of nerves mentioned in any of the works to which I have access, and it is peculiar that nerves to supply an outlying part like the mantle should take their course through so great a length of the body proper. Each visceral ganglion also gives off on its upper side a nerve to the posterior adductor, and these nerves vary, being sometimes single, sometimes forked. There is a small nerve from the outer side of the visceral ganglia to the mantle, following the line of attachment of the ascending lamellæ of the outer gill.

There is a marginal festoon of nervelets between the first and second posterior marginal nerves.

The cerebro-visceral connectives give off a small nerve a little behind the middle retractors (Fig. 17).

The nervous system of *M. latus* (Fig. 17) resembles that of *M.*

edulis (Fig. 18) in general disposition; but I cannot make a detailed comparison of their nervous system, as I had not time to dissect *M. edulis* fully. The arrangement of the nerves from the pedal ganglia seems to differ in *M. latus* and *edulis*; but I have not the particulars of their distribution in *M. edulis* (compare Figs. 17 and 18).

Reproductive Organ.

The general disposition of this organ is similar in the three species we are dealing with. The greater part of this organ lies in the mantle-lobes, and its ducts, branching throughout the mantle, converge to a common stem near the anterior end of the pericardium, below the retractors. From thence the ducts pass inward to the inner side of the base of the gills, and proceed backwards, one on each side of the mesosoma, between the ascending and descending lamellæ of the inner gill, opening in the genital papillæ near the hinder end of the mesosoma (*g d* and *g p*, Figs. 2 and 3). Part of the genital organ occupies the sides of the mesosoma, and the angles between the mesosoma and the mantle-lobes. The animals are diœcious, but the general plan of the organ and of its ducts is similar in both sexes. The males have the mantle-lobes whitish-yellow; the female are usually reddish: this point was noted also by Lacaze-Duthiers (12). The branches of the ducts in the mantle-lobes of *M. latus* seem to be not quite as superficial as in *M. edulis*—at any rate they are so obscure that it is difficult to define them; whereas in New Zealand specimens of *M. edulis* they are easily seen, although the ducts are not as wide as represented by Lacaze-Duthiers in the European *M. edulis*. The genital duct is readily traced on the ventral side of the organ of Bojanus, especially if distended with the genital products.

Are M. latus and edulis congeneric?

By reference to the following table and to the preceding pages it will be found that, while in the general plan of structure *M. latus* quite agrees with *M. edulis* and *magellanicus*, yet in the case of nearly all important organs there are considerable differences. While *M. edulis* and *magellanicus* agree so closely as to leave no question of their being members of one genus, there is a very considerable interval between them and *M. latus*. To pronounce definitely upon the above question would require an intimate knowledge of a great number of species of Mytilineæ, when it is possible that all intermediate stages between the above distinct forms might be found. My study of the internal structure has extended only to the three species mentioned in this paper, but, so far as this serves to decide, there

seems to be occasion for separating *M. latus* from the others if not as a genus, at any rate as a sub-genus. The following is a tabulation of the points of difference :—

MYTILUS LATUS.

Shell. Colour always more or less green; in the young often wholly green.
Hinge-teeth, one or two.
Muscle-impressions — three retractor impressions and one adductor impression.
Muscles. No anterior adductor.
Anterior retractor attached to the byssus.
Posterior retractors of the byssus separated into middle and posterior retractors.
Cavité des flancs. No trace of such a cavity.
Organes godronnés. Rudimentary.
Alimentary canal. Pyloric cæcum distinct from first part of intestine, extending into the mantle.
Circulatory system. Vascular system single and median.
Mantle in part supplied from posterior aorta.
Marginal or circumpallial artery present.
Posterior aorta very large.
A single median anterior gastro-intestinal artery.
Posterior gastro-intestinal arteries absent, replaced by posterior aorta.
Venous system in great part lacunar.
Oblique vein between middle and posterior retractors.
No marginal sinus.
Organ of Bojanus. Internal communication with pericardium lost.
Gills. Ascending lamellæ attached by their upper edge.
Interlamellar junctions few, and placed singly at the middle.
Mantle. Mantle-lobes joined posteriorly only by a short transverse bar.

MYTILUS EDULIS.

Shell. Colour deep blackish-blue; in the young the same, occasionally whitish-yellow.
Hinge-teeth, three or four.
Muscle-impressions — two retractor impressions and two adductor impressions.

MYTILUS EDULIS—*continued.*

Muscles. An anterior adductor present.

Anterior retractor usually attached to the foot.

Posterior retractors of the byssus united in one bundle.

Cavité des flancs. Of considerable size.

Organes godronnés. Large.

Alimentary canal. Pyloric cæcum forming one tube with first part of intestine, not extending past posterior adductor.

Circulatory system. Vascular system double and equilateral.

Mantle wholly supplied from aortic bulb or anterior aorta.

Marginal artery absent.

Posterior aorta small.

Two anterior gastro-intestinal arteries, and two posterior, in addition to the posterior aorta.

Venous system well defined.

Oblique vein anterior to the whole of the posterior retractors.

A marginal sinus present.

Organ of Bojanus. Communicates freely with the pericardium by a large couloir or passage.

Gills. Ascending lamellæ quite free at their upper edge.

Interlamellar junctions more numerous, and several placed together at the middle.

Mantle. Mantle-lobes joined throughout a great part of the posterior end.

METHODS OF RESEARCH.

A great part of the structure, as for instance the structure of the various parts of the alimentary canal, nervous system, &c., has of course been made out by the ordinary process of dissection, but with the vascular system it is necessary to have recourse to injection. The most convenient apparatus for injecting the mussel is a small injection-syringe provided with very fine nozzles made of glass tubing, these being attached by short lengths of indiarubber tubing. I have employed several materials for injection: (1.) As recommended by Sabatier (7), lard thinned with turpentine and coloured with vermilion or blue. This answers well enough for injecting, but the oil-bubbles that rise while dissecting under water are inconvenient. (2.) Plaster-of-Paris coloured red or blue. This is the most convenient, as it sets and maintains the form of the vessels while dissecting. (3.) A strong solution of gum-arabic coloured either with vermilion, carmine, or the prussian-blue precipitate obtained from salts of iron. This has one point of advantage over the plaster-of-

Paris in that longer time may be taken in injecting, as it does not set and obstruct the vessels. By putting the specimens injected with gum-arabic injection into spirits of wine the gum is precipitated in the vessels.

I have used chiefly the second method—that with plaster-of-Paris. The most convenient point for injecting the arterial system is the ventricle. A fine nozzle inserted into the ventricle can readily be pushed forward into the neck between the ventricle and the aortic bulb, and there firmly tied. The venous system can be injected from the oblique vein or from the foot. One of the best methods of preparing the mussels for injection is to remove the shell carefully above the pericardium, then to open the pericardium and the ventricle. In this condition the mussels should be placed back downwards, and allowed to bleed. Successful injections were often made in the case of specimens put for a day or two in weak spirits of wine.

SECTIONS (Figs. 41 to 44).

Another method of examining the mussels was by cutting vertical sections. By cutting thick sections with a sharp razor, holding the mussel firmly on a block with the fingers, many points can be made out; but for sections that are to be examined under the microscope special preparation of the tissue is necessary. The mussel, having been carefully removed from the shell, is hardened in absolute alcohol and stained with borax carmine, then set in a mould with melted caocao butter. Before surrounding it with caocao butter the mussel must be soaked in creosote. The slides are prepared by coating them very thinly with shellac, by which the sections are firmly attached to the slide. The sections are made by the use of a microtome and razor, and are arranged in order on the prepared slides. Then, by heating over a water-bath, and flooding repeatedly with turpentine, all traces of the butter are removed, while the sections themselves keep their places on the slides. The sections are then mounted in the usual way in Canada balsam. Of a very young *M. edulis* I cut a complete series of sections, there being in all 218 sections, and, of these, four from different regions are shown enlarged in Figs. 41, 42, 43, and 44. By this treatment many points concerning the histology of the tissues are clearly shown; but I have not had the time requisite for studying the histology. In explanation of the plate of sections:—

Fig. 41. [The side shown is the anterior side of the sections.] This is a vertical section, a little behind the anterior end of the anterior retractors, in the region of the labial palps and the gullet. The

gullet (*gul*) is seen to have longitudinal ridges, and above it is the supra-æsophageal cavity. Between the two labial palps (*o lp* and *i lp*) on each side are the gills (*gill*), and above their point of attachment the anterior retractors (*a rt*). The foot (*ft*) is represented between the mantle-lobes.

Fig. 42. This section is through the hind part of the base of the foot. The two anterior retractors (*a rt*) are still seen, and above them the stomach (*stm*). Below the stomach is a narrow part of the cardiac cæcum. On the left of the stomach to the dorsal side is the forward coil of the recurrent intestine (*rc int*)—note that the right hand of the plate is to the left of the mussel—and near the base of the gills is the returning coil of the intestine (*int*). The supra-æsophageal cavity ends a little in front of this section.

Fig. 43. This section is taken just behind the pericardium and in front of the posterior adductor. The posterior retractors (*p rt*) form a great part of the section. Above and between them are on the left the pyloric cæcum (*p c*), containing the crystalline style, on the right the recurrent intestine (*int*), and above them the rectum (*rect*). The space above the base of the gills is very lacunar.

Fig. 44. This section is taken through the region of the posterior adductor (*p ad*), which stretches across the section. Above it are the posterior ends of the retractors (*p rt*), and between these the pyloric cæcum (*p c*), with the recurrent intestine (*rc int*) leaving it and joined with it to the right. Above these is the rectum (*rect*). The cavity above the rectum in this and the preceding figure is enclosed by the joining of the mantle-lobes above the posterior adductor. Below the adductor are seen the two gills of each side.

EXPLANATION OF PLATES.

p ad	Posterior adductor.
a ad	Anterior adductor,
a rt	Anterior retractor.
p rt	Posterior retractor.
m rt	Middle retractor.
r ft	Retractor of the foot.
ft	Foot.
o l p	Outer labial palp.
i l p	Inner labial palp.
j m	Junction of mantle.
g d	Genital duct.
o gd	Organes godronnés.
mes	Mesosoma.
bys	Byssus.
man	Mantle.
stm	Stomach.
p c	Pyloric cæcum.
int	Intestine.
rc int	Recurrent intestine.
dir int	Direct intestine.
rect	Rectum.
gul	Gullet.
i g	Inner gill.
o g	Outer gill.
c g	Cerebral ganglion.
v g	Visceral ganglion.
p g	Pedal ganglion.
c v c	Cerebro-visceral connective.
c p c	Cerebro-pedal connective.
m n	Marginal nerve.
m n 1	First marginal nerve.
m n 2	Second marginal nerve.
m n 3	Third marginal nerve.
p n	Pedal nerve.
b n	Byssal nerve.
g n	Gill nerve.
t n	Tentacular nerve.
d m n	Dorsal marginal nerve.
a ao	Anterior aorta.
p ao	Posterior aorta.
a p a	Anterior pallial artery.
p p a	Posterior pallial artery.
a m a	Anterior marginal artery.
p m a	Posterior marginal artery.
ven	Ventricle.
aur	Auricle.
a b	Aortic bulb.
a v a	Anterior ventral artery.
p v a	Posterior ventral artery.
g a	Gastro-intestinal artery.
t a	Tentacular artery.
p a	Pedal artery.
tr a	Transverse artery.
r a	Recurrent artery.
l v	Longitudinal vein.
o v	Oblique vein.
h v	Horizontal vein.
m s	Marginal sinus.
a v	Anatomosing vein.
asc v	Ascending vein.
coul	Couloir pericardique.
per	Pericardium.
i l j	Interlamellar junction.
i f j	Interfilamentar junction.

PLATE I.

Fig.
1. Diagrammatic section of *M. latus*.
2. Ventral view of *M. latus*. The mantle-lobes are separated, and the gills are cut off near their base.
3. Ventral view of *M. edulis*, as above.

PLATE II.

4. Shell of *M. latus*, showing muscle-impressions.
5. Shell of *M. edulis*, as above.
6. Shell of *M. latus*, lateral view.
7. Shell of *M. latus*, dorsal view.
8. Sections through the dotted lines in Fig. 7.

PLATE III.

9. Muscles of *M. latus*, lateral view.
10. Muscles of *M. latus*, dorsal view.
11. Muscles of *M. edulis*, lateral view.
12. Alimentary canal of Dreissena, after Van Beneden.

PLATE IV.

13. Alimentary canal of *M. latus*, dorsal view.
14. Alimentary canal of *M. latus*, lateral view.

14A. Underside of stomach of *M. latus*, showing cardiac cæcum.

15. Alimentary canal of *M. edulis*, after Sabatier; *stm* = utricular stomach of Sabatier, and *p c* = tubular stomach of Sabatier.
16. Alimentary canal of *M. edulis*, after Sabatier.

PLATE V.

17. Nervous system of *M. latus*.
18. Nervous system of *M. edulis*, after Duvernoy.
19. Marginal nerves of *M. latus* (diagrammatic).
20. Pedal ganglion and surrounding muscles of *M. latus*.

PLATE VI.

21. Arterial system of *M. latus*.
22. Anterior aorta and pallial arteries of *M. edulis*.
23. The same of *M. magellanicus*.
24. Lateral view of arterial system of *M. latus*.
25. Arteries of *M. edulis*, after Sabatier.
26. The same.
27. Tentacular arteries of *M. latus*.
28. The same.

PLATE VII.

29. Pallial arteries of *M. latus*.
30. Pallial arteries of *M. magellanicus*.
31. Pallial arteries of *M. edulis*, after Sabatier.

PLATE VIII.

32. Venous system of *M. edulis*, after Sabatier.
33. Pericardium and longitudinal vein of *M. latus* (diagrammatic).
34. The same of *M. edulis*.

PLATE IX.

35. Transverse vertical section of *M. edulis*, showing gills (diagrammatic).
36. Single gill-filament of *M. latus*.
37. Same as Fig. 35 of *M. edulis*.
38. Single gill-filament of *M. edulis*, after Peck.
39. Part of gill-plate of *M. latus*, just behind the middle retractor; the mantle is cut off by the base of the gill.
40. Diagrammatic view of the arrangement of the middle interlamellar junctions of *M. latus*.

PLATE X.

41 to 44. Sections of *M. edulis*. (See previous explanations.)

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PLATE I.

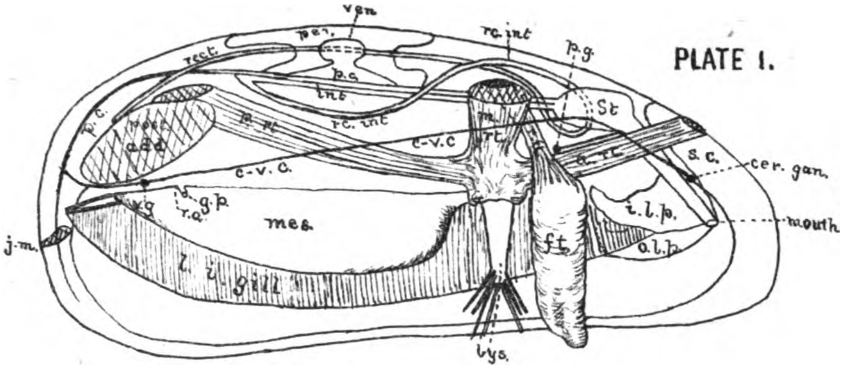


Fig. 1. M. latus.

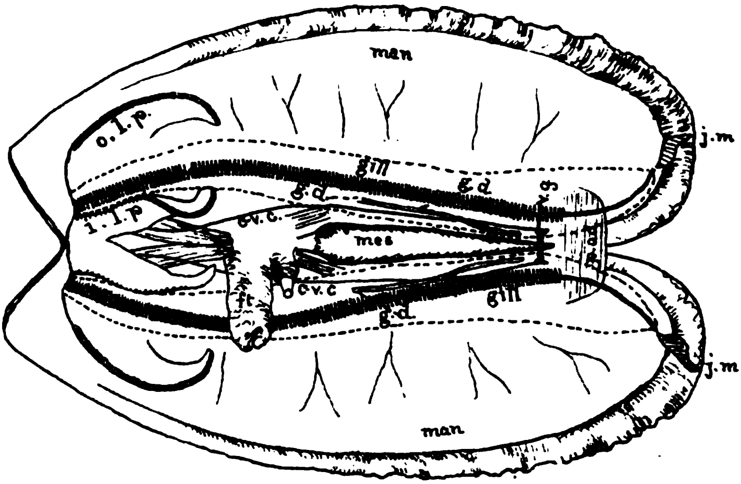


Fig. 2 M. latus.

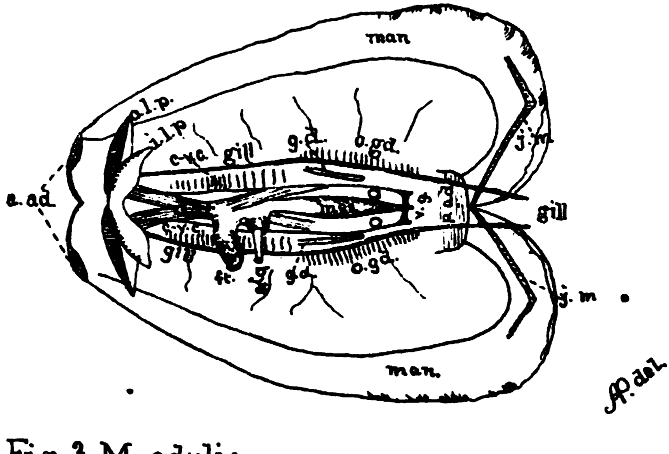


Fig. 3. M. edulis.

PLATE II.

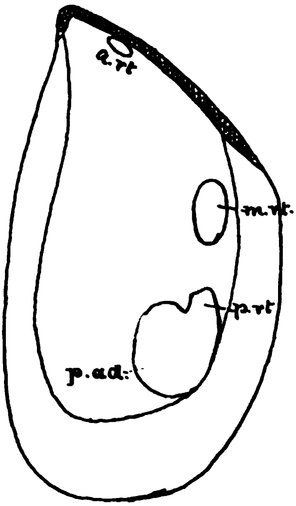


Fig. 4. M. latus.

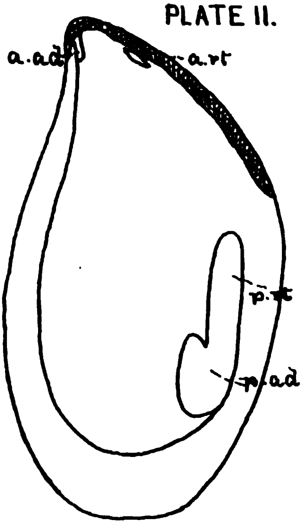


Fig. 5. M. edulis.

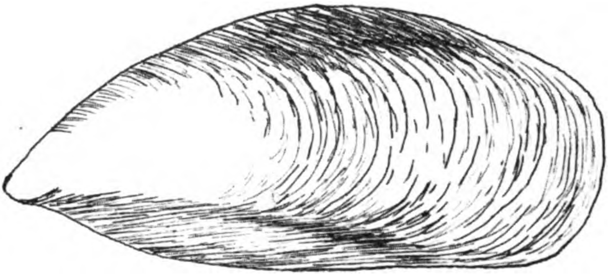


Fig. 6. M. latus.

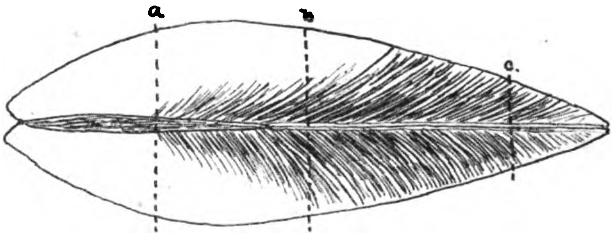


Fig. 7. M. latus.

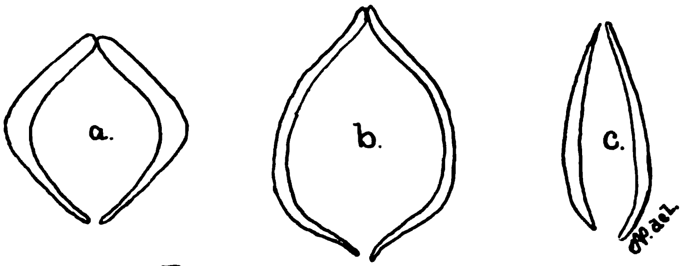


Fig. 8. M. latus.

PLATE III.

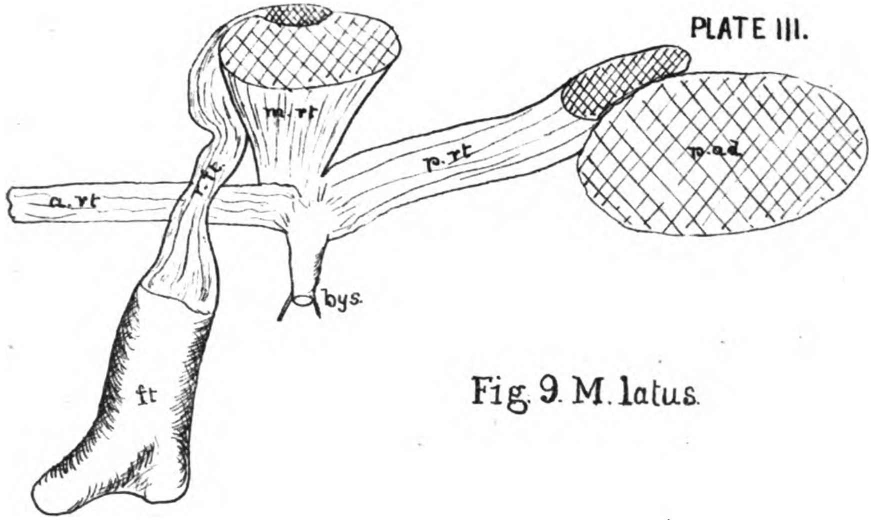


Fig. 9. M. latus.

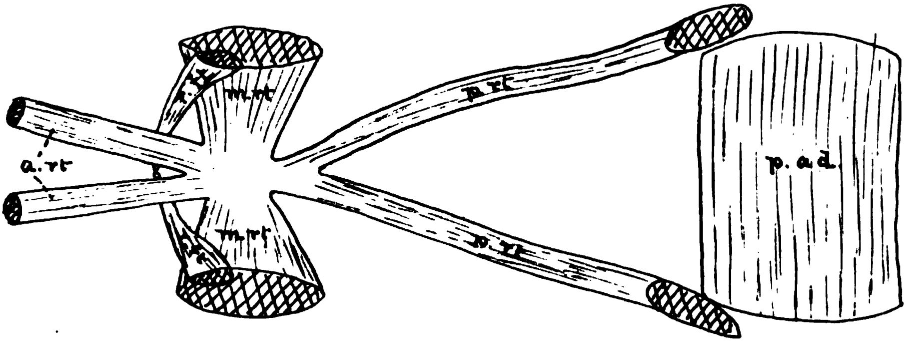


Fig. 10. M. latus.

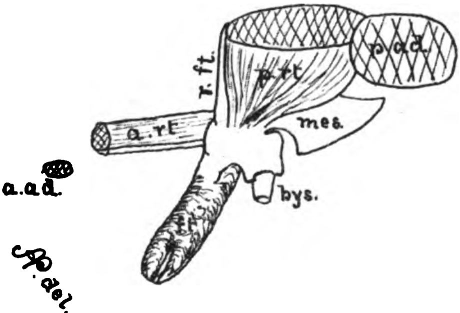


Fig. 11 M. edulis.

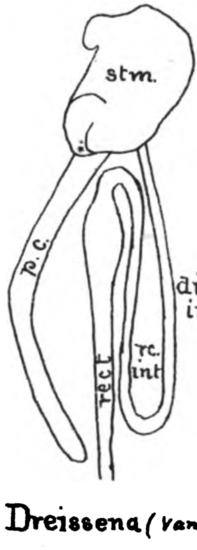


Fig. 12. Dreissena (Vanbeneden)

PLATE IV.

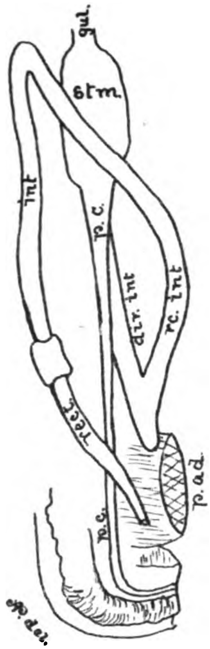


Fig. 13. M. latus.

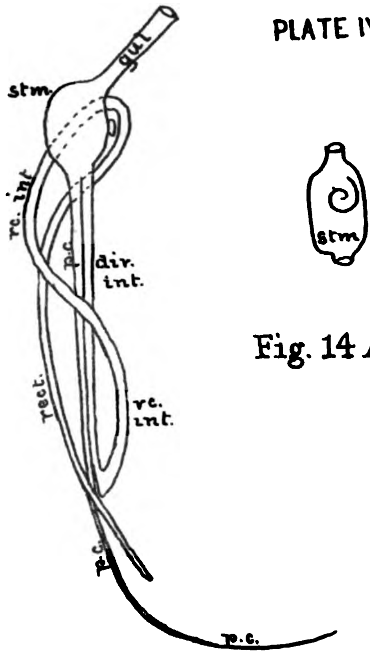


Fig. 14. M. latus.

Fig. 14 A.

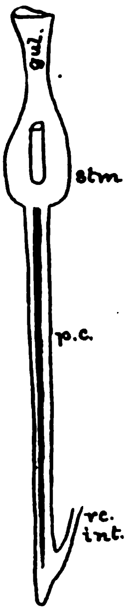


Fig. 15. M. edulis (Sabatier)

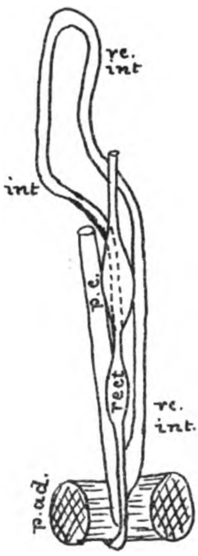


Fig. 16 M. edulis (Sabatier)

PLATE. V.

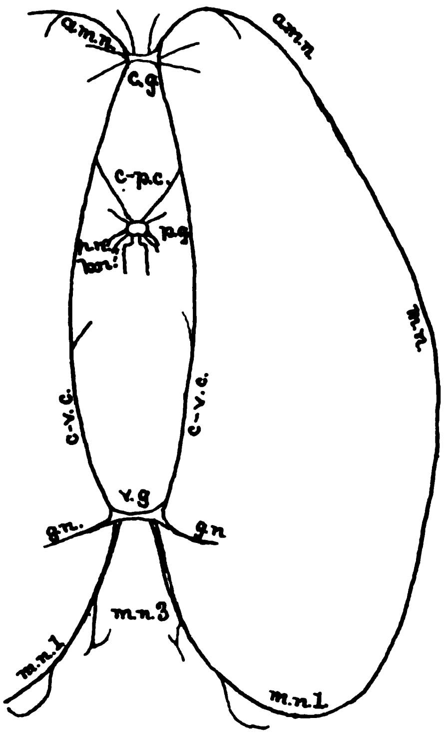


Fig. 17. M. latus.

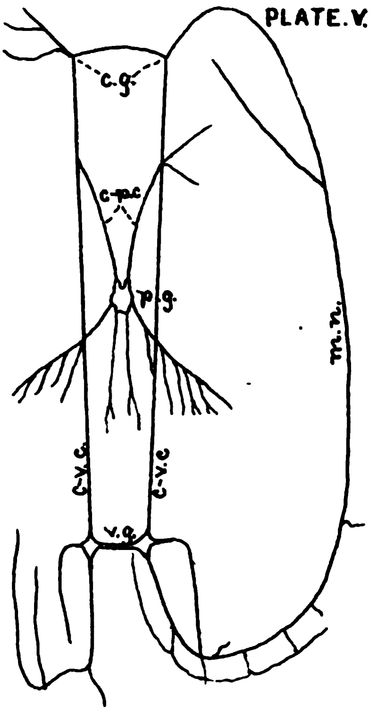


Fig. 18. M. edulis. (Duvernoy)

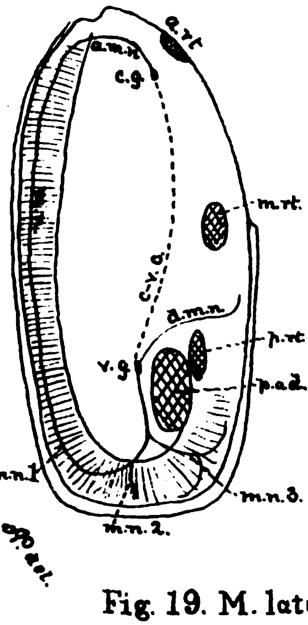


Fig. 19. M. latus.

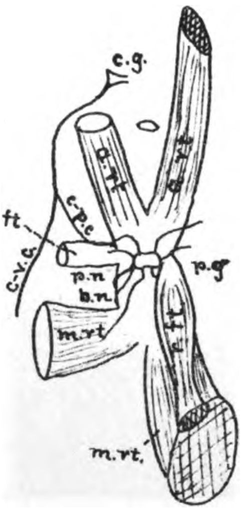
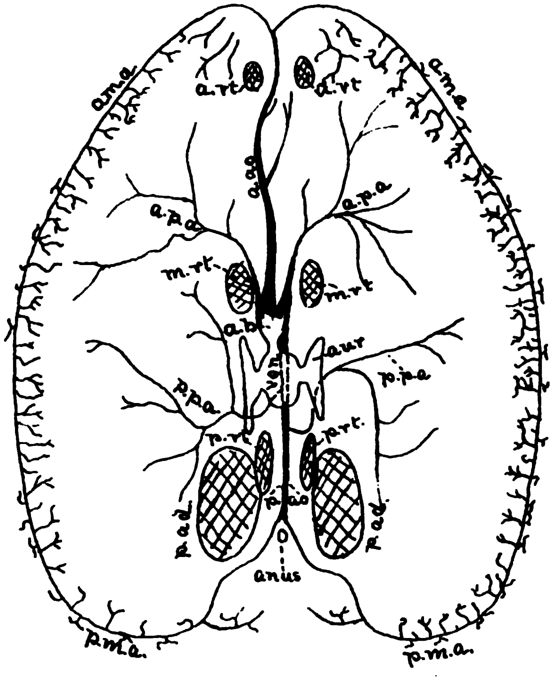


Fig. 20. M. latus.

PLATE. VI.



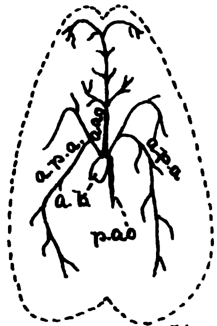


Fig. 22. M. edulis.

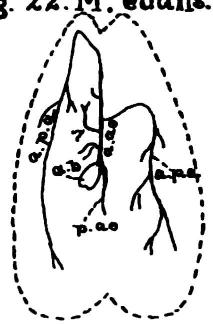


Fig. 21. M. latus.

Fig. 23. M. Magellanicus.

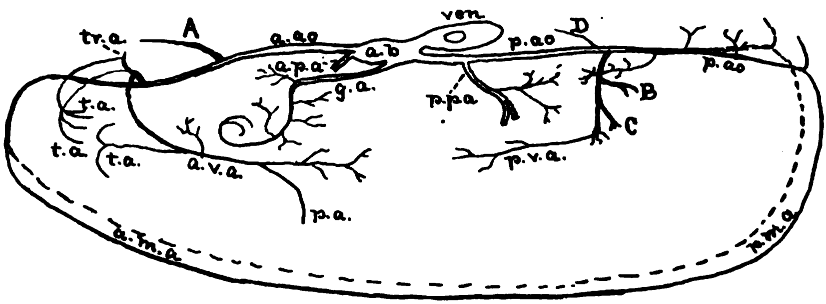
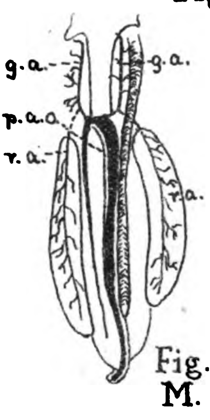


Fig. 24. M. latus.



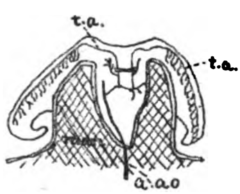


Fig. 27. M. latus.

Fig. 25. Fig. 26.
M. edulis. (Sabatier)

Fig. 28. M. latus.

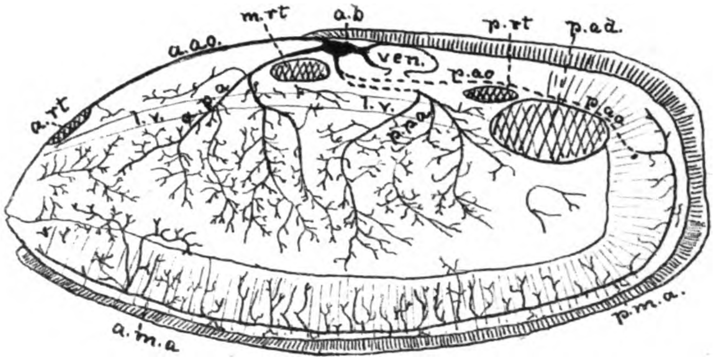


Fig. 29. M. latus.

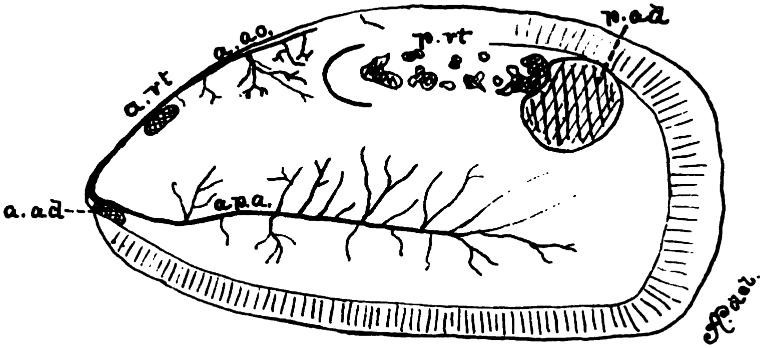


Fig. 30. M. Magellanicus.

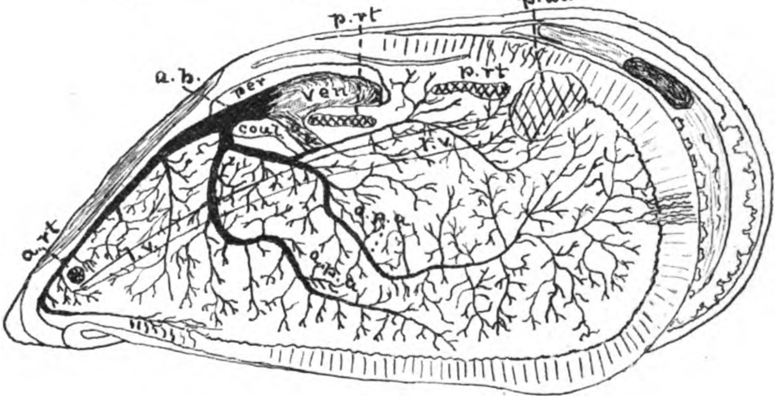


Fig. 31. M. edulis. (Sabatier)

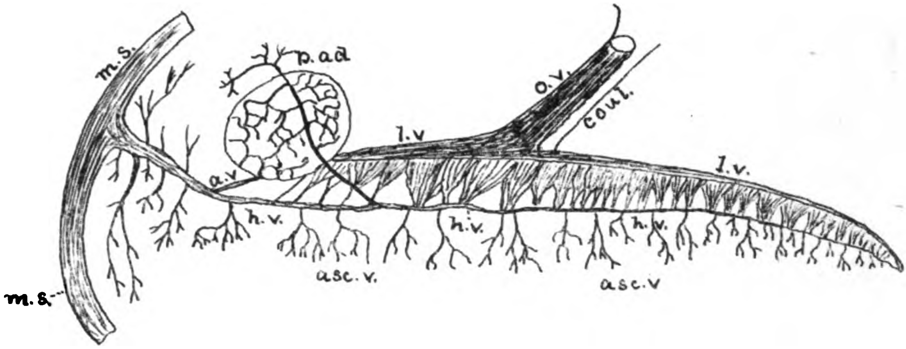


Fig. 32. M. edulis. (Sabatier).

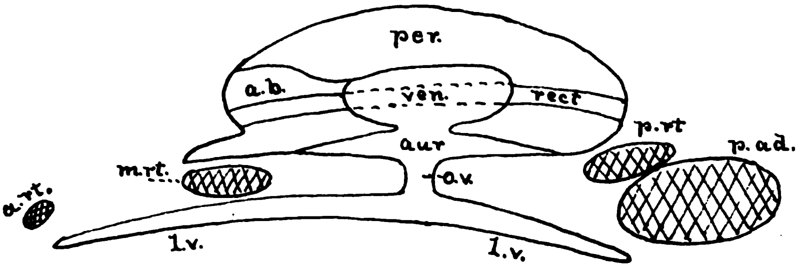


Fig. 33. M. latus.

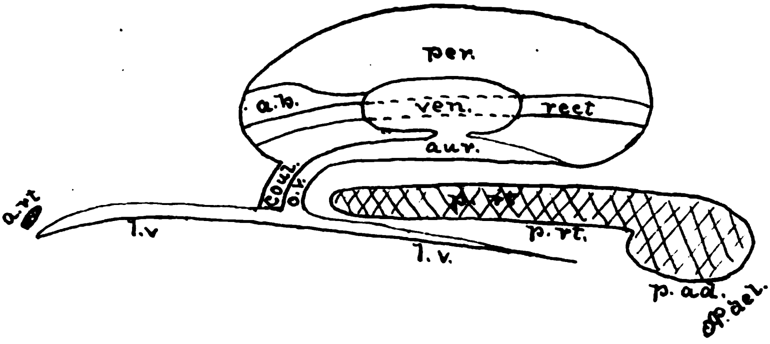


Fig. 34. M. edulis.

PLATE IX.

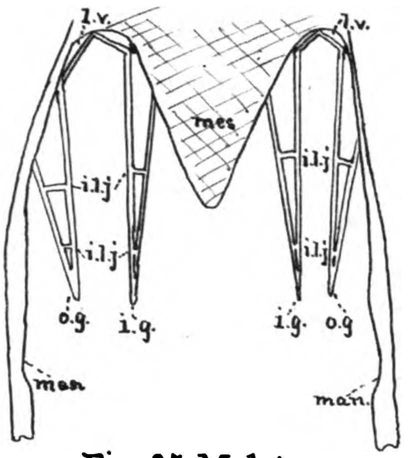


Fig. 35. M. latus.

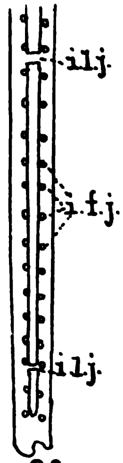


Fig. 36.

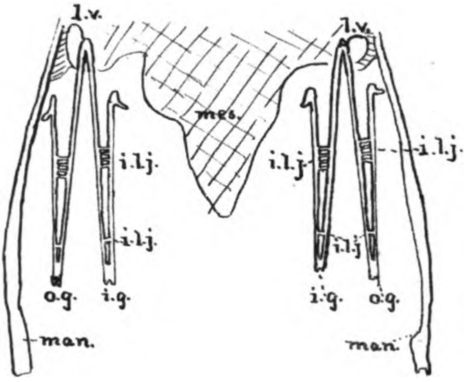


Fig. 37. M. edulis.

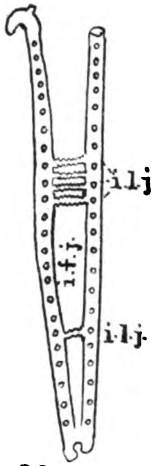


Fig. 38. (Peck).

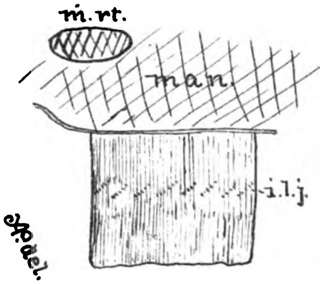


Fig. 39. M. latus.

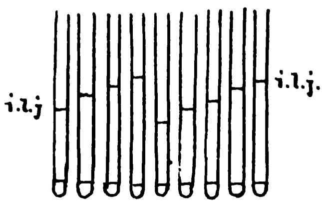


Fig. 40.

PLATE X.

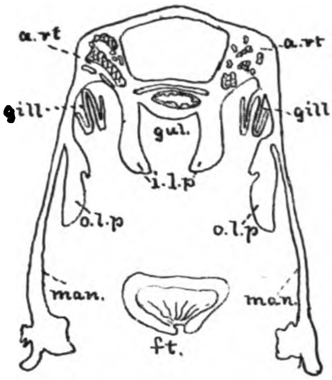


Fig. 41. M. edulis.

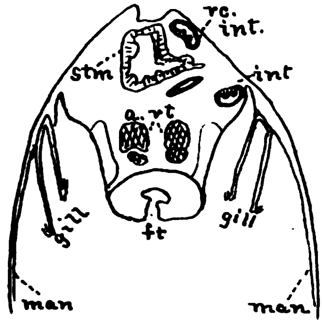


Fig. 42.

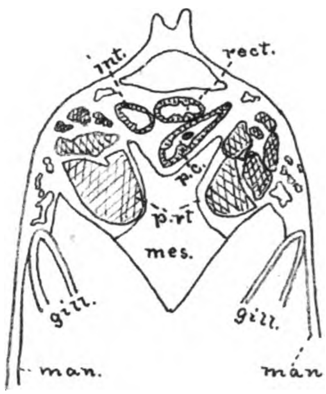


Fig. 43.

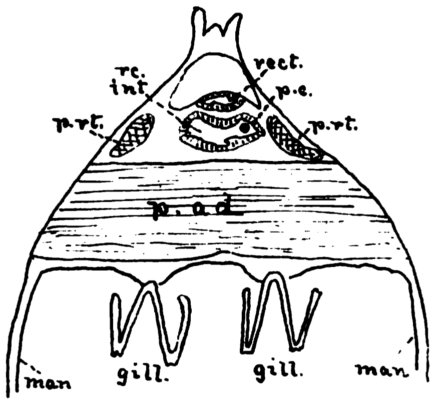


Fig. 44.

R. del.